

The Blast Furnace *and* Steel Plant

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No. 3

Joint Representation at Colorado Fuel

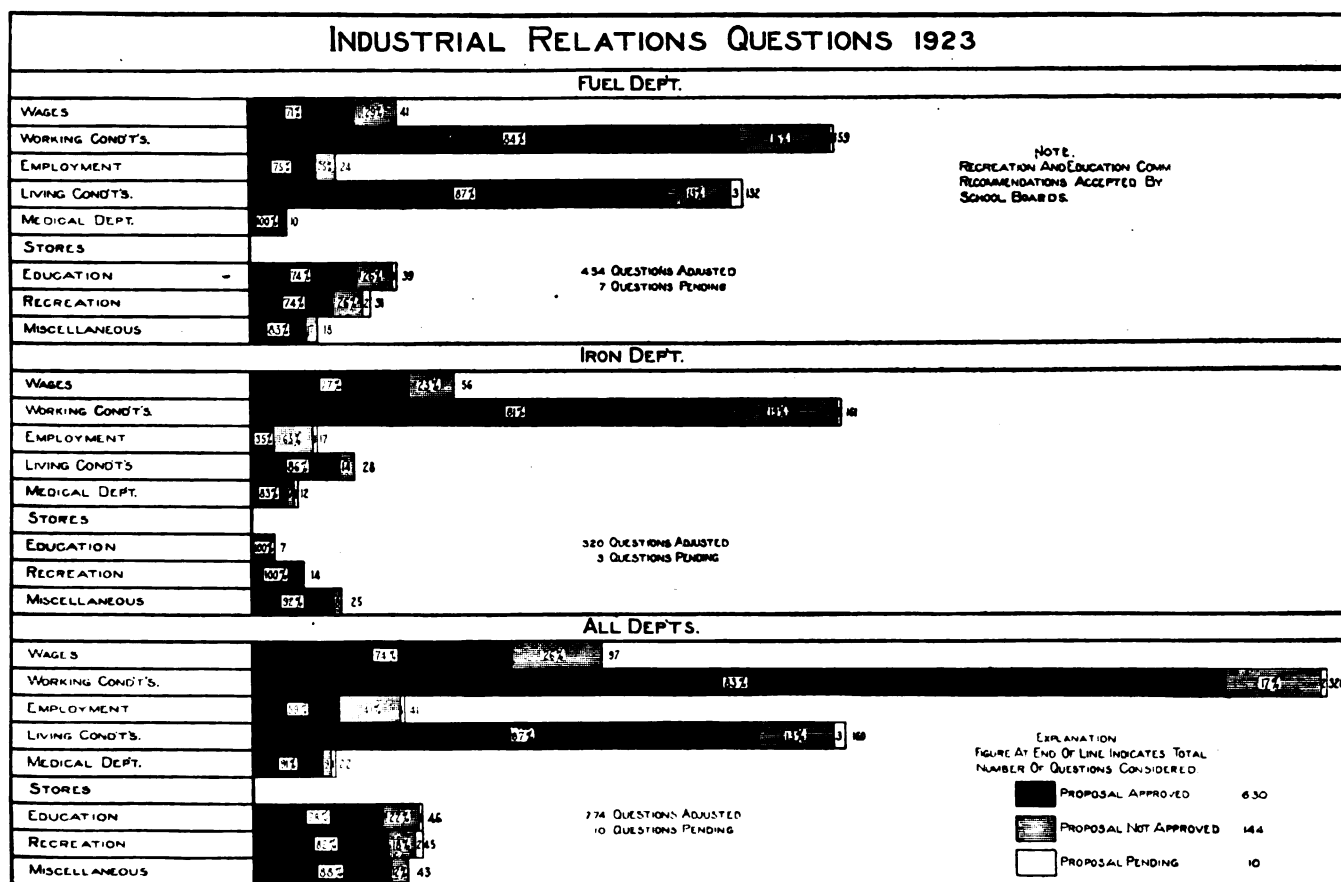
Joint representation has brought together employer and employe and has given each the opportunity of understanding the other's difficulties, aims and viewpoints. It has developed mutual confidence—confidence of the employer that the employe was willing to consider with fairness everything in which the well-being of either was concerned. It has developed confidence on the part of the employe that

abled each to see that the other was the kind of fellow who could be trusted.

It has to a large extent destroyed suspicion on both sides.

It has, in this company, increased efficiency of both management and employee.

Differences between employee and employer which constantly arise in industry are quickly settled and



his employer was concerned in his welfare and was anxious to help in bettering his condition and willing to give consideration to his problems in a way he had not believed.

A better understanding has been brought about by acquainting the employees with the varying business problems as they affect employees. It has in this way dispelled the ignorance of both parties, and has en

small grievances are prevented from becoming large ones.

Foremen do not act as impulsively as formerly. Employees do not quit on the spur of the moment when something seems to them wrong. Labor turnover is decreased.

It has brought about greater satisfaction and happiness in our industry.

Plant Two Power House

Remarkable Concentration of Motor Drives Makes Inland Steel Notable

By F. J. CROLIUS

PART III

LOCATED centrally within the rolling mills is, what is termed Plant Two Motor Room, which houses all the main drives and regulating equipment, and is also a continuation of the new power house necessary for the generation of power for the new mills. The generating equipment, as installed at that time, consists of two 5,000-kva. turbo-generator units, 2300 volts, 25 cycle, 3 phase, and are connected to a bus structure located in the basement. This structure is built of special brick, the barriers between the buses being transite board, 2 inches thick. Bus bars are supported by heavy pedestal type insulators, held in place by means of bolts set in special concrete blocks. This structure carries a single bus circuit and contains necessary switching apparatus for the different main drives, transformer stations, main pumping stations, and main breakers for the syn-

In the January and February issues, the general features of the Inland Steel Company plant at Indiana Harbor were shown. This final instalment concludes the description with further details of a remarkable motor-drive assembly.

chronous motor-generator sets for the conversion of power from a.c. into d.c. There were two synchronous motor-generator sets originally installed, but one more has been added lately. These three units are 1,000-kw., 250-volts, d.c., and are of the same make and operating characteristics.

Due to other departments being added at this plant, such as rail finishing equipment, splice bar and tie plate units, it was necessary to increase the capacity of this station. There has been added one 12,500-kva. turbo-generator unit, 2300 volts, 3 phase, 25 cycles, connected to a separate bus structure, parallel with the original structure, and located in a dust-proof leanto outside of the main building.

The two structures are electrically tied together by means of an oil switch with instantaneous trip and set for the full load capacity of the large unit. In case of a disturbance on any of the feeder circuits, the tie switch will open and cut the large unit off the original, lighter bus structure. This was thought necessary, as the interrupting capacity of the original feeder switches was not sufficient to take care of the increased generator capacity under short-circuit conditions. Also, duplicate feeder switches were installed in the new structure for all important circuits, and with the necessary connections and disconnecting switches duplicate bus conditions were obtained.

The switchboard at this station is located over the original bus structure on the same floor as the generator units. This switchboard contains controlling and metering equipment for the generators and feeder circuits, voltage regulators, exciter buses and exciter starting equipment. Provision is also made for excitation of the generators from the d.c. bus, in case

of trouble with the exciters. Also controlled from this board, are the tie line switches. These switches are in duplicate on the different structures and are 2300 volts, 2500 amp. capacity, and tie plant two motor room buses to the original a.c. low pressure station buses located in plant one. Distance between the stations is about 3,000 feet and the feeders are 1,000,000 c.m. cable per phase.

The tie line is in three sections, due to having part of this line installed in a tunnel. At the junction of these sections are mounted special disconnecting switches, located in concrete houses at the foot of the towers. Also at this point are installed two sets of transfer switches which can be thrown to either side of the main disconnecting switch.

The second section of the switchboard consists of starting and metering equipment for the three synchronous motor-generator sets. Each set has its own feeder switch in the main structure, the starting switches being located back of their respective panels.

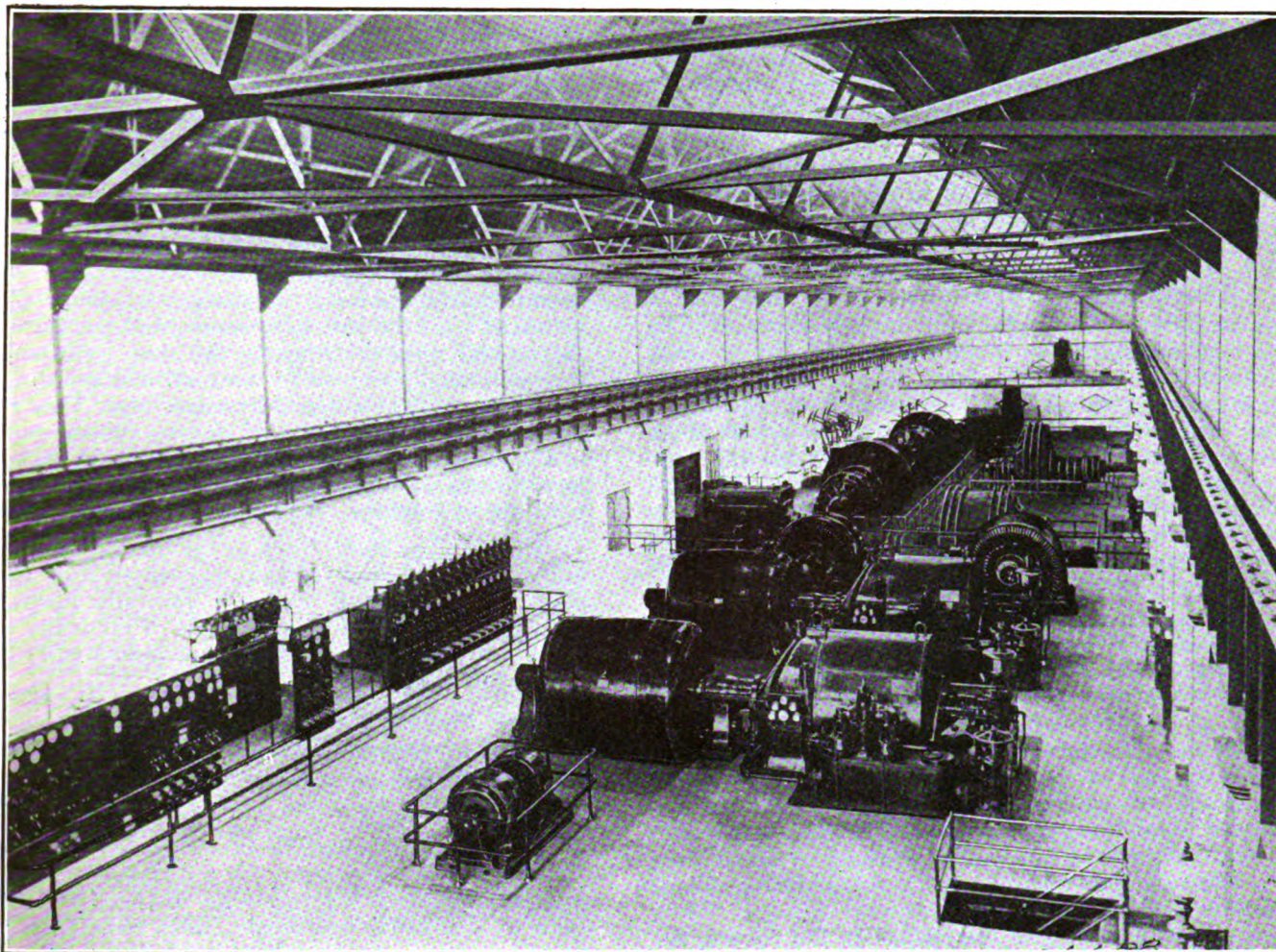
The third section of the switchboard consists of three d.c. generator panels, one d.c. tie line panel, four 4,000-amp. feeder circuits, six 2,000-amp. feeder circuits. Two of the generator panels are equipped with the necessary switches and resistance for reversing the operation of these machines, in case of emergency.

In a scheme of this kind it is imperative that no constant speed, shunt wound motors having flywheels, such as shears, presses, etc., are connected on the circuits, as the counter e.m.f. of these motors feeding back on the line after breaker has opened at power house, would cause the operating magnetic coils to lag, thereby delaying the action of the spring and causing the load on the crane magnets to drop. The high pressure fire pumps for the coke plant department are also fed from the d.c. tie line circuit. The constant speed motors at plant two are 440-volt a.c., and are supplied from a transformer station located in the motor room. This station consists of four 500-kva., single-phase transformers, 2200 to 440 volts, one transformer being equipped with necessary switches to be thrown on any phase, and is used as a spare.

Description of Electrical Equipment in Various Departments in Plants One and Two.

Plant One is a complete steel making plant in itself, depending on plant two only for hot metal from the blast furnaces for use in the open hearth department. The open hearth department consists of 12 furnaces of 50 ton capacity each, and has an output of approximately 46,000 tons of steel per month. This department is served by three scrap handling magnet cranes, one cast house coal handling gantry crane, one stock crane, two hot metal cranes, five hot metal cars, three crane type charging cars, three 100-ton ladle cranes, one 25-ton floor crane, one 15-ton pit crane and one stripper.

South of the open hearth department are located 15 soaking pits, necessary for the 36-in blooming mill.



Plant Two Power House. This is a remarkable grouping of turbo-generators, mill motors, and control apparatus.

The 36-in. mill is steam driven, the manipulators and screw down being hydraulically operated. All other auxiliary drives, such as tables, shears, transfers, etc., are electrically operated. This mill acts as a roughing mill for the 24-in. billet mill and 24-in. sheet bar mill, the steel being rolled direct on these mills from the 36-in. bloomer without reheating.

The 24-in. billet mill is in line with the 36-in. mill and rolls billets for the 14-in. Morgan continuous mill. The 24-in. billet mill is driven by a constant speed engine, having a large flywheel mounted between the engine and the mill to take care of the peaks incidental to a mill of this kind. The 24-in. billet mill engine also drives the roughing stand of the 24-in. sheet bar mill.

The 24-in. sheet bar mill finishing stand is driven by a 1500-h.p., 2200-v., 3-phase, 25-cycle, 368 r.p.m. induction motor, speed of the rolls being reduced to 93 r.p.m. by means of a suitable reduction gear, running in oil. Material from this mill is cut into different lengths required by means of a steam operated flying shear. Adjustable speed motors are installed on shear tables and regulate the speed of delivery of the bars to comply with the operating speed of the flying shear. Sheet bar rolled on this mill is piled for shipment by means of a pinch roller on a vertical cradle piler. Pinch roll is driven by an adjustable speed motor to enable the operator to vary the speed to comply with the different weights of the bars.

As the 36-in. blooming, 24-in. billet and 24-in. sheet bar mills are in the same building, most of the cranes serve the different departments. The total crane equipment for these departments is two soaking pit cranes, one 40 ton mill crane, three five ton mill cranes, two 25 ton billet yard cranes and two hot bed cranes. The 25 ton cranes can be taken into the different engine rooms when work is to be done on the engines. The hot bed cranes take material from the piler to hot beds and from the hot beds to cars for shipment. The 36-in. blooming mill also rolls billets for the 24-in. bar mill. This material is put onto skids by means of a hydraulic pusher. These skids are directly opposite the reheating furnaces for the 24-in. bar mill and material is transferred to the furnaces by cranes. The 24-in. bar mill is a four stand mill, the first stand being universal for the rolling of universal plates. Material rolled on this mill are structural shapes, from 3 in. x 2 in., angles to 12 in. I-beams. The usual practice on this mill is to roll universal plates while they are changing finishing rolls for different sections. The mill is driven by a twin-simple, reversing engine. Material is transferred from one stand to another, from either side of the mill, by means of chains and dogs, operated by hydraulic rams. All table rolls in this department are motor driven, as is also the screw down on the universal mill. The product is taken from the mill over tables and past saw to hot bed, across hot bed to hot bed table, through a leveler, to warehouse,

where it is sawed or sheared, as the case might be, and loaded on cars for shipment.

The crane equipment in this mill consists of one mill crane, one hot bed crane and three warehouse cranes. All saws, shears, levelers and gaggers are electrically operated.

The sheet mill consists of two units, number one unit being electrically driven, while number two unit is driven by a cross compound steam engine. Number one unit drive is a 1600-h.p., 2200-v., a.c., 3-phase, 25-cycle, 210 r.p.m., wound rotor, induction motor. Speed of the rolls is reduced to 28 r.p.m. by means of a triple staggered tooth gear unit, entirely encased. The flywheel is installed on this drive to take care of peaks incidental to work of this kind. This motor operates on a fixed resistance of six per cent in the secondary and steps of 11 and 16 per cent can be obtained by means of the master controller. Number one unit consists of nine stands of sheet mills, one jobbing mill and three stands of cold rolls. Number two unit consists of seven stands of sheet mills, one jobbing mill and four stands of cold rolls. All shears, stokers, fans and levelers are electrically driven.

The galvanizing department is located south of the sheet mills and consists of eight standard galvanizing pots, having individual drives. The motors are 15 h.p., 230 v., d.c., adjustable speed, 425 to 1275 r.p.m., to permit operator to set pot speed according to the material he is galvanizing. The galvanized sheets are carried by conveyors from the pots to the warehouse where they are inspected, weighed and shipped. All fans, conveyors and levelers are motor driven. The crane equipment consists of two cranes to serve the galvanizing pots and picklers and one crane in the warehouse.

Located next to the warehouse is the roofing department. This department is equipped with necessary corrugating, stamping machines and presses for the finishing of sheets used in building construction. This building is a continuation of the sheet mill warehouse and shipping department, and is served by two cranes. All machinery in this department is electrically operated, with the exception of the patent levelers, which are operated by steam.

The continuous merchant mill consists of 14-in. roughing and 11-in. and 8-in. finishing. This mill rolls rounds, squares and deformed bars for reinforcing concrete work. The mill is driven by a tandem, compound steam engine, 3500 h.p., 150 pounds steam pressure. All roll tables, transfers and twisting machines are motor driven. This mill is served by three cranes, one at the furnaces, two at the finishing and shipping ends.

Plate Mill: The 30-in. x 100-in. plate mill is of the tandem type having roughing and finishing stands. Both stands are driven by 2200 v., a.c. induction motors. Number one unit, or roughing stand, is driven by 2000-h.p., 2200-v., 3-phase, 25-cycle, 245-r.p.m., wound rotor induction motor. Peaks on the motor are controlled by means of liquid slip regulator in the secondary of the motor. On the occasion of a heavy load, the resistance is inserted in the secondary winding, tending to slow the motor down and allow the flywheel to give up part of its energy. The speed of the mill is reduced to 52 r.p.m. by means of a suitable rope drive, with the larger pulley acting as a flywheel.

Number two unit, or finishing stand, is driven by 3000-h.p., 2200-v., 3-phase, 25-cycle, 245-r.p.m., wound

rotor induction motor, having the same general characteristics and control as the roughing mill. All tables, screw downs, transfers and shears are motor driven. This department is served by seven cranes, two acting as charging cranes, two mill cranes and three at the finishing and shipping end. All of the charging is done by means of magnets, and also a large percentage of the shipping and inspection is handled by magnets.

Bolt and Rivet Department: Bolt and rivet department operates approximately 75 motors on the different machines, such as lathes, shapers, planers, grinders, etc., in the tool room, and on nut, rivet, thread and spike machines in the shop. All machines are individually driven by motors, and quite a number have adjustable speed by rheostats. This adjustment of speed is necessary, due to the manufacture of a wide range of sizes. This department makes different sizes of bolts, rivets, spikes and special track bolts for rail splices. They also turn out silo rods.

Shops: The shops, such as the main machine shop, boiler shop, locomotive shop, carpenter shop, pattern shop and blacksmith shop are centrally located, together with the general storeroom. Practically all the machines in the various shops are individually driven by electric motors.

Total number of cranes in plant one—75.

Total number of motors in plant one, not including cranes—574.

Plant Two.

The western boundary of Plant No. 2 is on the Indiana Harbor ship canal, for a distance of 3,000 feet, and forms a dock for receiving material from boats, such as ore, stone and coal. Boat unloading equipment consists of five combination bridges and unloaders for ore and stone and two high speed unloaders for coal. The ore bridges are also used for the unloading of coal, when conditions warrant same.

Ore and stone is unloaded from the boats to storage yard and over storage yard to larry cars, then to the furnace storage bins. From the storage bins the ore is weighed on scale cars and then moved on to the skip hoists. The skip hoists are steam driven. However, material is on hand for the changing of these drives to electric.

The blast furnace department consists of one 500 ton and two 550 ton furnaces, and supplies all the iron for plants one and two open hearth furnaces, also pig iron for company use and for the trade.

The supply of coal for the coke plant is practically all delivered in boats. The coal is unloaded from boats by unloaders to track hopper, and by belt conveyor for a distance of some 600 feet to a cross belt conveyor running parallel to the coal storage field and extending the entire length of the field. The coal is delivered from belt conveyors on coal bridge and deposited in any space desired in the field. Due to the fact that the unloaders, working with the bridges, could unload faster than the belt conveyor could take it away, thereby causing considerable delay, a large storage hopper was built at the dock and is used for storage of coal unloaded by ore bridges. This hopper is equipped with a cross belt conveyor which empties on the main belt conveyor to the coke plant storage. After boats have been unloaded, the dock hopper is opened and coal conveyed to the main storage. This

method cut down the time to unload approximately 50 per cent.

All equipment, such as larry cars, conveyors, crushers, door machines, pushers, etc., are electrically operated, the only steam driven apparatus being installed in the by-product department. Coal is taken from the storage yard and put into the crushing system by use of two coal bridges.

Plant Two Open Hearth.

This department consists of ten 85-ton furnaces and one 600-ton hot metal mixer. All doors and valves on the furnaces are hydraulically operated. The mixer is operated by two motors, either motor being large enough to handle the work alone. Each motor has its own control panel and master control; the master controllers are mechanically interlocked together, but can be readily separated. There is also provided a dead man limit switch, mounted over and above the running masters. It is necessary for the operator to hold the dead man switch while operating the mixer, and if, for any reason, he should let go of the switch, the mixer immediately would return to its upright position. If, for any reason, the limit switches should fail to operate, they can be short-circuited by means of a four pole switch within the operator's reach. The emergency feed, described in another part of this article, makes this installation very reliable.

The open hearth department is served by two mold yard cranes, three scrap handling magnet cranes, one bucket crane for stone and limestone, two 75-ton hot metal cranes, two 150-ton ladle cranes and one strip-per crane.

Under construction in this department are four 100-ton furnaces, all doors and valves to be electrically operated, and one 175-ton ladle crane.

Located at plant two open hearth are the skull-cracker cranes. Two 25-ton skull cracking cranes are installed and they handle all the skulls from open hearth and blast furnaces.

40-Inch Mill.

The 40-in. mill is one of the latest designs in rolling mill equipment and is entirely electrically operated. The mill proper is driven by Westinghouse, double unit, reversing equipment, consisting of special fly-wheel motor-generator set, main motor and necessary masters and control. The complete outfit is under the control of the operator located in the rollers pulpit, by means of a drum type master control, vertically operated. The motor-generator set consists of a 3000-h.p., 2200-v., 3-phase, 25-cycle, 368-r.p.m., wound rotor, induction motor, one 45-ton flywheel and two special generators. The fields of the generators are separately excited, and with full excitation, generator voltage is 600. By reversing the direction of the field current, the armature current is reversed, and, as the main motor is directly connected to the generators, reversal of the generator armature current reverses the motor armature current, thereby reversing direction of rotation of the main motor. The speed of the main motor is under the control of the operator and is adjustable from 0 to 120 r.p.m. in either direction, in 16 steps. The peak input to the motor-generator set is regulated by means of a liquid slip regulator connected in the secondary of the 3000 h.p. drive motor. When the load on the motor reaches the predetermined setting, the regulator opens and inserts resistance in the motor

secondary, tending to slow same down and allow the flywheel to give up part of its energy. The main roll motor weighs approximately 270 tons and is connected to the pinions of the mill by means of a suitable universal coupling.

All of the 40-in. mill auxiliaries are motor driven. A feature worthy of mention is that all the motors on the mill proper, i. e., tables, manipulators, screw down and fingers, are supplied with washed air from an air conditioning system located in the main motor room. Due to this method of operation, we have very little trouble with the electrical equipment of this mill.

The crane equipment in this mill consists of two soaking pit cranes, two mill cranes and three billet dock cranes.

The 40-in. mill rolls, from the ingot, slabs for the plate mill and blooms for the 32-in. mill. The slabs for the plate mill are slid off the table rolls by means of a grass hopper pusher and carried by a conveyor to a special piler car. The blooms for the 32-in. mill are taken off table rolls by means of chain conveyor to skids in back of the reheating furnaces and are then taken care of by an electric pusher, which forces material through the furnaces.

The 32-in. mill is a roughing mill for the 28-in. mill. The 32-in. mill is entirely electrically driven, the main motor having the same operating characteristics as the 40-in. mill motor, but being a single unit.

The 28-in. mill motor is also a single unit, having the same operating characteristics as the 32-in. and 40-in. mill motors. Due to the fact that the 28-in. mill is a three-high mill, the motor is operated in one direction, but is so designed that it can be reversed, as are the other motors. Control for all three motors is identical. The intention of having a motor of this design on a mill of this kind was to enable the operator to pick up a large beam slowly and to stop the motor instantly at will. The motor-generator set supplying current to the 28-in. and 32-in. mill motors is a double unit, one generator being used for each mill. The driving motor of the set is rated at 5000-h.p., 2200-v., 3-phase, 25-cycle, 368-r.p.m., wound rotor, induction motor and is considerably larger than the 40-in. mill. This is necessary, as there are practically no idle periods on a mill of this type, one or two bars being in the rolls at all times.

The tables of this mill are of the traveling, tilting type, the motors of which are supplied with current from conductor bars in a pit located at the back of the tables. The operators are on a cantilever pulpit, directly over the mill, and they do not travel with the tables, as in some mills of this type. There are two sets of hot saws located near the hot beds of this mill. One saw is of the sliding type, for use on structural shapes, and two saws on adjusting rails of the drop type are used when rolling rails. Structural shapes rolled on this mill, after having been cooled on hot beds, are straightened, cold sawed or sheared to specified lengths in warehouse, and loaded for shipment.

Rails, splice bars and hot worked tie plates, are stored in No. 2 warehouse, and are conveyed to the different departments where they are finished, inspected and loaded for shipment.

All the auxiliary equipment in the 32-in. and 28-in. mills and finishing departments are electrically driven.

The 28-in. and 32-in. mills are served by two 75-ton cranes and one 15-ton crane. No. 1 warehouse, splice bar and hot worked tie plate departments are

served by four 15-ton cranes. No. 2 warehouse and the finishing end are served by three 15-ton cranes. Total cranes in plant two—60.

Number motors in plant two, not including cranes—557.

At the present time the following additions to Plant 2 mills are under construction:

Four 100-ton open hearth furnaces are being added to the battery, making 14 furnaces in all.

A 14-in. merchant mill built by the Morgan Construction Company is under construction. The mill has six stands of 18-in. roughing rolls and four stands of 14-in. finishing rolls. The mill will roll rounds and squares from $\frac{7}{8}$ in. to 3 in., beams and angles up to 3 in., and channels up to 4 in.

This mill will be driven by a 4,500-hp. adjustable speed Kraemer set. The reheating for this mill is to be done in two Morgan continuous furnaces 13 ft. wide

and 40 ft. long. The furnaces are to be fired with producer gas furnished by Morgan mechanical producers.

A six stand 24-in. continuous mill is being installed in line with the 40-in. blooming mill to roll billets and light slabs without reheating. This mill will be driven by a 6,250-hp., 2,200-volt a.c. motor.

The addition of the mills now under construction together with the numerous small auxiliary motors being installed throughout the works necessitates the installation of additional generating capacity. After a thorough survey and study of the present power system and future power requirements for additional electric driven mills and the probable electrification of existing steam driven mills, it was decided to install the first unit in a new power station located at the blast furnace. It is the intention, as future demands for power require, to add more units to this station, making it the main power station of the works.

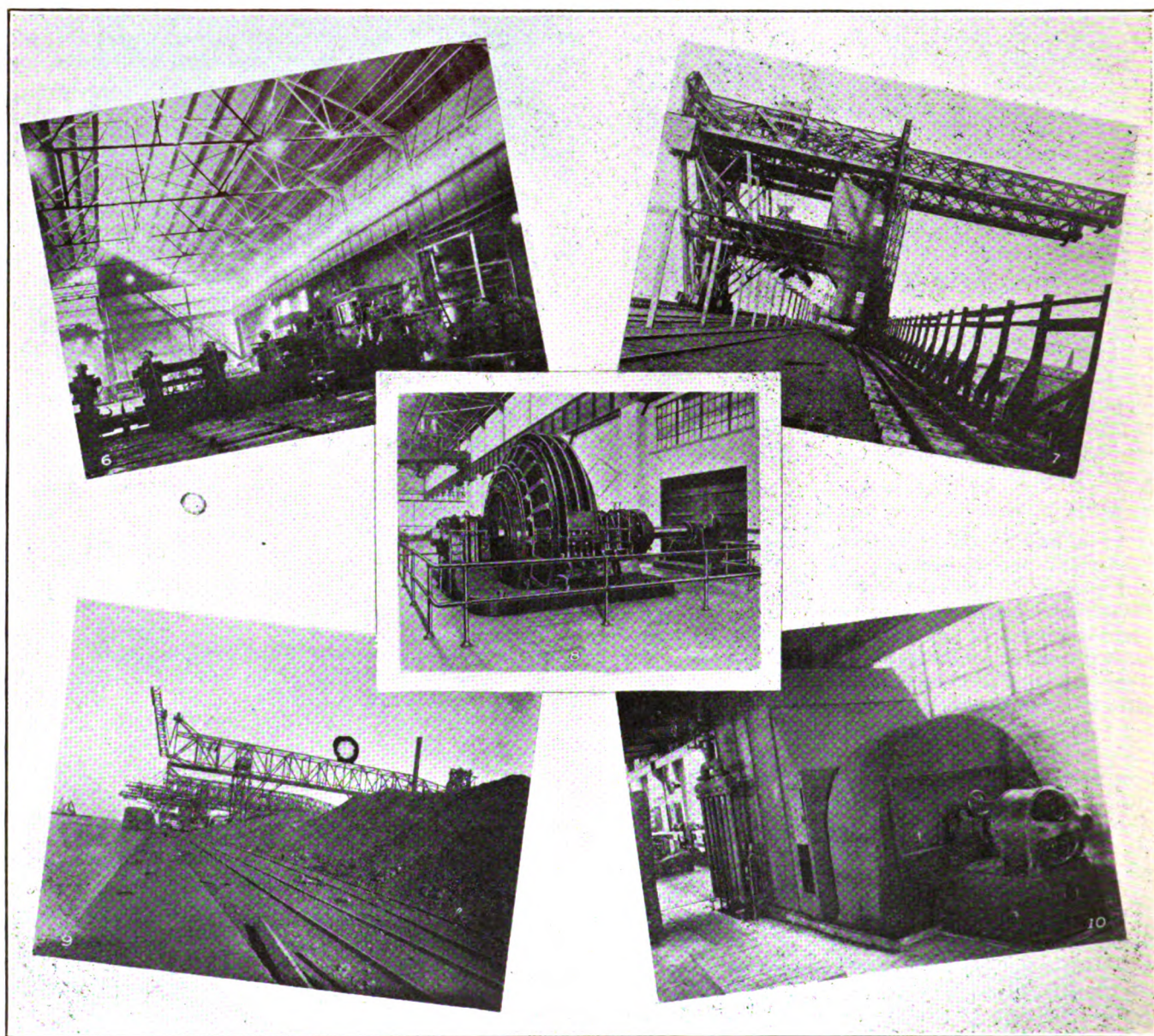


FIG. 6—The 24-in. structural bar mill. Universal plates are rolled during periods of finishing pass roll changes. FIG. 7 — The Hoover & Mason coal unloaders. There are two of these which in combination with transfer cars distribute the total coal supply. FIG. 8—28-in., 3-stand, 3-high structural mill motor. One of the group located in Plant Two Power House. FIG. 9 —A view of the five ore bridges, showing lake steamer at dock. FIG. 10.—Heating plant at the main machine shop motor and fan end.

Turbine Room.

In the turbine room is being installed a 12,500-kva. turbo-generator, built by Westinghouse Electric & Manufacturing Company, designed to carry full capacity, 90 per cent power factor, and having its most economical point at 9,000 kw. load. The turbine has a structural steel foundation, which is built around the condenser. The condenser has 15,000 sq. ft. surface and is provided with duplicate sets of duplex air ejectors. The condenser is also provided with duplicate condensate pumps, which will be motor driven. It is intended that, as the plant is extended in the future, one of the air ejectors and one of the condensate pumps will also act as a spare for the second machine installed. The steam used by the air ejectors is condensed by a small auxiliary condenser, the condensate being circulating water, so that such heat as may be in this steam is recovered in the main feed. To provide for starting up when the amount of condensate is very small but the full amount of steam is being used by the air ejector, a by-pass is provided so that water from the feed tank can be fed to the suction of the condensate pumps, thereby augmenting the amount circulated through the air ejector and condenser.

For cooling the generator an enclosed air washing system is installed; it is a totally enclosed system, the same air being circulated over and over again, the water sprays in this case having only a function of cooling the air. A thermostatic device is provided so that, if the temperature of the air entering the generator should rise above 100 deg. F., dampers will be operated automatically to open the inlet and discharge ducts to the atmosphere.

Boilers.

At present two boilers are being installed with integral economizers. The boilers have a heating surface of 12,045 sq. ft. and the economizers 6,740 sq. ft. They are designed for a working pressure of 300 lbs. per sq. in. and superheat of 200 deg.

These boilers will be fired with blast furnace gas, there being four burners to each boiler. The burners are being furnished by Surface Combustion Company.

The induced draft fans are driven by d.c. motors, the speed of which will be regulated to maintain balanced draft. Each boiler is provided with a stack 7 ft. in diameter, mounted on top of the fan. The boilers will be individually set.

Feed Water.

It is proposed to use only distilled water for feed water for these boilers, and such loss as occurs will be made up by two Griscom-Russell evaporators working double effect. Steam is furnished the evaporators through a reducing valve and a desuperheater, in which water from the feed line is sprayed into steam to saturate it. The raw feed water for the evaporators is first preheated in a small open heater. The vapor from the evaporators is used for heating the feed water and is discharged direct into the main heater.

The feed pumps are turbine driven and exhaust against about 5 lbs. back pressure into the main feed heater. These pumps are of the Cameron type, driven by Westinghouse turbines.

The main feed heater is of the deaerating type, manufactured by Griscom-Russell Company. This heater is arranged to operate under vacuum corre-

sponding to the feed temperature and is so arranged that the feed water is deaerated, so as to avoid pitting of economizer tubes. The heater is provided with a storage tank at the bottom of 2,000 gallons capacity and the level in this tank is maintained constant by regulating the feed water entering the heater from the main feed tank. The main feed tank is elevated above the heater and has a capacity of approximately 10,000 gallons. The discharge from the condensate pumps flows into this tank, as well as drains from the evaporator cells.

Chinese Inventions and Discoveries

The remark of Gore about Western civilization, that "the origin of many important discoveries lies buried in the obscurity of past ages," is none the less true of Chinese inventions and discoveries. Whether we believe with Jespersen that the flexionless Chinese language represents a higher linguistic development than the flexional languages such as Latin or Greek or whether with Taylor that "Chinese would take rank with English as a world language" and that "the Chinese come out near the apex of human evolution," or not, we nevertheless would admit the fact that some of the fundamental discoveries and inventions of great import to the human race have been made or forestalled by the Chinese. In fact, China is self-contained, with a virtually continuous existence of 5000 years, developing step by step through various discoveries and inventions by her people. Truly, in the words of Faber, an eminent sinologue, "China forms a World in itself."

I shall enumerate a few of the important discoveries and inventions of China as indicating in a way the general trend of her development.

The Compass: Records show that Chow Kung in the Chow Dynasty, about 1122 B. C. used a kind of wagon equipped with an instrument that pointed always toward the north.

Paper was first made by Tsai Lun, out of tree fibres, rags and hemp, during the Dynasty of Eastern Han, the early part of the first century.

Printing: It has been mentioned that Fung To originated the art of stereotyped wooden plates about the year 932 A. D., but later investigation made by the sinologue Stanislas Julien has shown that the invention actually dated from the year 593. A record of this period proves this: "It was decreed that drawings and unpublished texts should be collected and engraved on wood for publication."

Glass was first manufactured by Pun Fang about the early part of the second century. It is recorded that he had a piece carved with 130 designs.

Seismograph: An instrument, resembling perhaps the present day seismograph, was invented by Chang Heng in the first century, during the Han Dynasty, which could record any slight earthquake not perceptible by human senses.

Metals: In Tai Hao's time (2852-2737 B. C.) metallic coin was already in circulation. The inventive genius of the ancient Chinese can nowhere be more explicitly shown than in the art of making alloys. An alloy, similar to German silver, under the name of Pait'ong, was obtained by fusing "red steel" with arsenic. The manufacture by the ancient Chinese of gongs and tom toms, with their perfect tones, still remains to us a mystery, although their chemical composition has been determined.

THE SAFETY CRUSADE

Safety Work of the Bureau of Mines

By H. FOSTER BAIN, Director

Safety in industry is distinctly a modern problem. Most probably a number of the toilers who built the Pyramids were injured and killed by the breaking of the ropes and other mechanical devices with which they put the heavy stones in place, but such occurrences can hardly have made much impression except upon the unfortunate victims and their fellow workers. Industrial work was done at that time, and for many centuries thereafter, mainly by slaves, injury to whom could hardly awaken much more concern than injury to a domestic animal, with which they shared the status of ownership. Not until the industrial worker became a citizen of the state did his personal welfare become an object of general concern. In the middle ages there were so many other hazards to life that industrial hazards were overshadowed. Evelyn and Pepys in their diaries have given us a vivid picture of the tornado-like epidemics of disease that swept over Europe from time to time. It is estimated that over 60 million of the inhabitants of Europe died from smallpox in the eighteenth century. And our custom of shaking hands on meeting has its origin in a state of society in which it was fair to assume that any one met on the road or in the street was a possible enemy. So much progress has been made since then that such conditions seem unreal as an ugly dream. With the exception of influenza, medicine now knows how to control epidemics; murders, except among the criminal stratum of society, are infrequent; and industrial hazards now come out in relief, just as the candle shines when the electric lights are turned off.

Industrial hazards have, however, increased actually, as well as relatively, through the enormous advance of mechanization of industry. This makes an important additional reason why we should do something about accidents in industry. The words I have just used are significant, "do something." When the importance of accidents in industry was realized the accent was on doing and the weakness of the word "something" was not so apparent. In many cases what to do was clear; if men were injured by falling into holes the obvious thing to do was to put fences around the holes, and to attempt to teach men to look where they were going. This sounds easy, and it is probable that many of those who early took up "safety first" with enthusiasm thought that accident prevention would be easy once people put their minds on it. A decade of experience has not confirmed this optimistic view. Accident prevention proves unexpectedly difficult and we are being forced to view that no such measure of nearly complete success as has been achieved, for example, in the prevention of small-pox, will ever be possible. This is not an entirely fair comparison, however, because industrial accidents never claimed the number of victims that small-pox did, and just as in chemical

manufacture it is relatively easy to take out the gross impurities but difficult to remove the last traces, so we must recognize that in dealing with industrial accidents we are working in the zone where improvement is difficult.

It was inevitable that *doing* would focus attention on the second word of the pair, "do something." From its inception, the Bureau of Mines has had this viewpoint in a large degree, feeling that the mining industry should and could be relied on to do the things that it was evident should be done when attention was focused on them. Our job in many cases has been to so direct attention and we lay no claims of priority of discovery as to many of the dangers against which we have issued warnings.

Beyond this, however, has been the very large problem of first finding out what to do before starting to "do something." Explosions in coal mines afford a good example. It was generally known that mixtures of gas and air are explosive. It was much less generally known that coal dust alone was explosive and few appreciated how commonly dust permitted the spreading through a mine of what would otherwise have been a minor local gas explosion. No one knew exactly what to do about it. So it was necessary, not only to demonstrate beyond dispute by large scale tests and exhibitions the dangerous nature of coal dust, but to determine causes and formulate methods of prevention or limitations. It is in this latter field that, by common consent, the Bureau of Mines finds its peculiar field of usefulness. Under our system of dual government, regulatory powers in the mines rest with the states but where, prior to formulating regulations extensive and expensive research in technical matters is required, there is obvious economy in the states acting through the Federal government, and thus avoiding duplication and disagreement. The Bureau spent approximately a quarter of a million dollars in its five years work on dust barriers at its experimental mine near Pittsburgh. Obviously it would be poor economy to have each of the 29 coal mining states duplicate this work, and while the amount spent may seem large it is to be remembered that the property damage alone in one coal mine explosion is often larger.

Development of permissible explosives has decreased the danger of disasters in coal mines and the use of rock dust will undoubtedly limit the area affected in the case of such explosions as continue to occur. The Bureau has, in this case, pointed the way. It remains for the industry to make the application.

There remain many problems to be solved. The high speed at which mining is done in the United States and the limited amount of labor available and to be available necessitates the wider and wider introduction of machinery underground. This in turn means the use of electricity throughout the workings and each new force applied brings new dangers. It is entirely possible to guard against them and permissible electric machinery

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is now being developed to parallel permissible explosives, but all this requires research.. Before doing we must know what it is safe to do and in this as in other lines of work the Bureau of Mines is endeavoring to answer the question, "What?" asked in response to the urge to "do something" to lessen the number of deaths and injuries that have been so unwelcome an accompaniment to the task of removing hundreds of thousand million tons of mineral yearly from deep within the earth and making it available for the service of man.

American Engineering Council

The organization of the American Engineering Council now constitutes a Federal System analogous to that under which the Government of the United States functions, says Gardner S. Williams of Ann Arbor, Mich., in a prepared statement interpreting the Council's Revised Constitution. The new constitution permits the reelection of the president, an office now occupied by former Governor James Hartness of Vermont. The statement of Mr. Williams, who is a vice-president of the Council, follows:

"The first change in the revision is the dropping of the name 'Federated American Engineering Societies' and replacing it by 'American Engineering Council' which now stands for the association of societies. The administrative and legislative body, formerly called the American Engineering Council is now designated the Assembly. The name of the Executive Board is changed to Administrative Board and the Committee on Procedure becomes the Executive Committee.

"By the analogy it may be said that the constituent Societies correspond to the States in our national government and like them have delegated certain powers to a national organization. This organization, American Engineering Council, therefore corresponds to the United States. The Assembly then is analogous to Congress and the Administrative Board may be said to roughly represent the President and his Cabinet. It may be pointed out that by reason of the method of selecting delegates to the Assembly the latter partakes of the nature of a Senate rather than a House of Representatives, while in its representation proportioned to membership it resembles the House rather than the Senate.

"The next change is in the provision for membership where it is made possible for technical sections or divisions of non-engineering organizations to be admitted to membership, as well as alumni associations of engineering schools and sections of non-member national societies, none of which seemed to be included under the original constitution.

"The Assembly is specifically directed to 'through appropriate channels communicate to the proper representatives of the National Government opinions, advice and suggestions relative to questions of legislation or administration in the solution of which engineering and allied technical knowledge and experience may be involved or valuable;' and is authorized 'upon request of local or state organization, or in the absence of such organizations (to) render similar service in local and state affairs.'

"The former function has been regularly exercised by the Council since its organization, but was never specifically provided for in the constitution.

"The past-presidents are made members of the Assembly for six years following the expiration of their service as Presidents, in order that their judgment and experience may be available to the Council.

"A provision is introduced making possible a reduction of membership on the Administrative Board below thirty, the former requirement.

"The most important change is in Section II of Article IV, wherein the established practice of the Council is written definitely into the Constitution as follows:

"'Limitations: No decision affecting the policy or action of American Engineering Council shall be made by the General Assembly or the Administrative Board unless it shall receive a two thirds affirmative vote:

"'(a) Of the representatives present of each of the national member societies having six or more representatives on the Assembly.

"'(b) Of the aggregate of the representatives present of the other national member societies.

"'(c) Of the aggregate of the representatives present of the local, state and regional member societies.

"These limitations shall not apply to the election of officers, the eligibility of representatives, the admission of members, the determination of assessments, the payment of bills, the adoption of a budget, the amendment of the 'By-Laws' or 'Standing Rules,' the selection of a place and time for a subsequent meeting, or matters of a purely routing nature.'

"This provision prevents any hasty or illconsidered action being taken over the opposition of even a comparatively small minority, and assures substantial unanimity on all matters of major importance. It gives to each of the large national societies the power to stop action and should fully answer the charge that they may be swamped by the votes of the smaller local societies.

"The old provisions regarding the setting up of state councils and relations to state affairs have been dropped.

"The By-Laws now appear as 'By-Laws and Standing Rules.' The former embrace those practices which have been found while the latter include matters upon which a final conclusion has not yet been reached. The former can only be amended by a vote of the Assembly while the latter can be changed by the Administrative Board.

"The membership is now restricted to organizations 'of the United States,' it being recognized that the Council's functions are primarily to deal with our National Government from the standpoint of its citizens and that there can be no proper participation of foreign societies therein.

"A qualification for Representatives on the Assembly has been inserted which is practically equivalent to that of the second grade of Corporate Membership in the great national societies. This assures men of similar qualifications on the Assembly to those met in the governing bodies and on the Committees of the national societies.

"In the Standing Rules provision is made for alternates both on the Assembly and Administrative Board, it being the belief that the more persons who can be brought into close touch with the work of the Council the more strongly will it become entrenched in the engineering profession."

By replacing the armature return spring of their types G and M demand meters with an electromagnet, the General Electric Company have made it possible to eliminate false registration due to failure of supply voltage. This development also allows the use of these types of meters with the type D-3 or so-called three-wire contact device, thus minimizing the danger of false registration due to improperly adjusted contacts. This construction is now available in the G-2, M-4 and allied types of meters.

Metalloids in Basic Pig Iron in Basic Open-hearth Practice*

By C. L. KINNEY, JR.†

PART II

THE first section of this important discussion appeared in January Blast Furnace and Steel Plant, pages 45-50. "An endeavor to emphasize the effect of varying percentages of silicon, manganese and phosphorus in the basic open hearth process, on the cost of steel; supplemented by calculations that exhibit the monetary losses sustained, when unnecessary quantities of silica or bases are used."

THERMAL BALANCE SHEET

Heat Absorbed

THERMOCHEMICAL CHANGES

Reduction of oxides of iron:

Heat of formation of $\text{Fe}_2\text{O}_3 = 3240$ B.t.u.Heat of formation of $\text{FeO} = 2430$

Input:

 $\text{Fe}_2\text{O}_3 = 6781$ $\text{FeO} = 100$

Heat of formation:

 $\text{Fe}_2\text{O}_3 = 3240 \times 6781 = 21.97 \times 10^6$ $\text{FeO} = 2430 \times 100 = 0.24 \times 10^6$

Total =

 22.21×10^6

Output:

Tapping slag = $\text{FeO} = 1644 \times 2430 = 3.99 \times 10^6$

Moisture in ore:

Total weight of ore = 8462 lb.

Per cent = 8.20

Total water = 694

Total heat to make steam at 212°

 $694 \times 1092 = 0.76 \times 10^6$ Specific heat of steam = $0.42 + 0.00013 \times$ $(2800 + 212) = 0.81$ Heat in superheat = $694 \times (2800 - 212) 0.81 = 145 \times 10^6$ Total = 2.21×10^6

Decomposition of limestone:

Heat of formation CaCO_3 per lb. = 772 B.t.u.

Total limestone = 4478

Total heat required = $772 \times 4478 = 3.46 \times 10^6$

Moisture 1.5 per cent = 67

Total heat to make steam = $67 \times 1,092 =$ 0.07×10^6 Heat in superheat = $2,096 \times 67 =$ 0.14×10^6

Total =

 3.67×10^6

Decomposition of improperly burned dolomite:

Total weight of dolomite = 2500 lb.

Volatile = 15.54 per cent = 389 lb.

Assumed 98 per cent 389 = 381 exists as CO_2 To drive off $\text{CO}_2 = 1756$ B.t.u. per lb.Total heat to drive off $\text{CO}_2 = 1756 \times 381 = 0.671$

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TABLE 7.—Standard Iron, Low-silica Ore, Furnace Charge

CHEMICAL BALANCE SHEET

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Material	Weight in Pounds	Per Cent. C	Pounds C	Pounds CO	Per Cent. Si	Pounds Si	Per Cent. SiO_2	Pounds SiO_2	Per Cent. P	Pounds P	Per Cent. P_2O_5	Pounds P_2O_5	Per Cent. Mn	Per Cent. MnO	Pounds Mn	Per Cent. S
Basic hot metal.....	65,000	4.30	2,795		0.75	488		1,039	0.20	130			1.00		650	0.04
Structural steel scrap	35,000	0.20	70						0.01	4			0.40		140	0.04
Low SiO_2 ore (natural)	8,462						4.62	391	0.017	1			0.07		6	0.006
Michigan limestone.....	4,478						0.34	15	0.006							0.042
Calced dolomite.....	2,500						1.32	33	0.004							0.126
Fluorspar.....	300						1.12	3	0.004							
SiO_2 from furnace structure.....								100								
Total entering furnace.....			2,865			488		1,581		185					796	
Total steel in bath.....	99,552	0.20	199						0.01	10			0.23		230	0.04
Tapping slag, 100.97 per cent.....	8,975						17.61	1,581		125	3.18	286		6.70	466	0.25
Total output.....			199					1,581		135					696	
Unaccounted for.....															-100	
Metalloids oxidized.....			2,666			488				125					566	

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Material	Pounds S	Per Cent. CaO	Pounds CaO	Per Cent. MgO	Pounds MgO	Per Cent. Fe	Pounds Fe	Per Cent. FeO	Pounds FeO	Per Cent. Fe_2O_3	Pounds Fe_2O_3	Per Cent. Al_2O_3	Pounds Al_2O_3	Per Cent. CaF_2	Per Cent. Volume	Per Cent. Moisture
Basic hot metal.....	26						60,911									
Structural steel scrap.....	14						34,772									
Low SiO_2 ore (natural)	1	0.96	81	21.12	179	56.09	4,746	1.18	100	78.82	6,781	1.10	93		1.68	8.20
Michigan limestone.....	2	54.60	2,445	0.88	39	0.20	9					0.30	13			1.50
Calced dolomite.....	5	48.58	1,215	32.58	815	0.38	10					1.49	37		15.54	
												R_2O_3				
Fluorspar.....		2.50	8	0.38	1							1.15	3	92.53		
SiO_2 from furnace structure.....																
Total entering furnace.....	48		3,749		1,034	99.52	100,448						146			
Total steel in bath.....	40						99,074									
Tapping slag, 100.97 per cent.....	22	41.77	3,749	11.52	1,034		1,274	18.32	1,644			1.62	146			
Total output.....	62		3,749		1,034		100,343						146			
Unaccounted for.....	+14						-100									
Metalloids oxidized.....							100									

THERMOPHYSICAL CHANGES

Hot metal = 65,000 lb. Temperature = 2474° F.
 Tapping temperature = 3030° F. includes emissivity factor
 Temperature rise (3080 — 2474) = 606° F.
 Specific Heat = 0.2
 Heat absorbed = $65,000 \times 606 \times 0.2 = 7.88 \times 10^6$
 Scrap = 35,000 lb. Temperature = 62° F.
 Melting temperature scrap = 2795° F.
 Heat required to bring to melting temperature = $2733 \times 35,000 \times 0.16 = 15.30 \times 10^6$
 Latent heat of fusion = 72 B.t.u.
 Total heat of fusion = $35,000 \times 72 = 2.52 \times 10^6$
 Heat to raise to temperature of bath $35,000 \times 285 \times 0.2 = 2.00 \times 10^6$
 Total heat = 19.82×10^6
 Total heat in molten slag:
 Heat in tapping slag = $8975 \times 1066 = 9.57 \times 10^6$ B.t.u.
 Total heat absorbed = 62.04×10^6 B.t.u.

Heat Generated

Oxidation of carbon, weight = 2666 lb.
 Heat of formation of CO from C per lb = 4374 B.t.u.
 Heat generated = $4374 \times 2666 = 11.66 \times 10^6$
 Oxidation of manganese, weight = 566 lb.
 Heat of formation of MnO = 2984 B.t.u.
 Heat generated = $2984 \times 566 = 1.69 \times 10^6$
 Oxidation of silicon, weight = 488 lb.
 Heat of formation of SiO₂ = 11,693 B.t.u.
 Heat generated = $11,693 \times 488 = 5.71 \times 10^6$
 Oxidation of phosphorus, weight = 125 lb.
 Heat of formation of P₂O₅ = 10,825 B.t.u.
 Heat generated = $10,825 \times 125 = 1.35 \times 10^6$
 Heat of formation of slag, weight = 8975 lb.
 Heat of formation of slag = 114 B.t.u.
 Heat generated = $8975 \times 114 = 1.02 \times 10^6$
 Total heat generated = 21.43 B.t.u.

Authorities for Constants Used

THERMOCHEMICAL CHANGES

Iron oxide reduction—Richards
 Decomposition of limestone—U. S. Bureau of Standards
 Oxidation of C, Mn, Si, P—Richards, LeChatelier, Berthelot, Thomson
 Formation of slag, calculated using Richards' values

THERMOPHYSICAL CHANGES

Specific heat, pig iron—0.1665—Oberhoffer
 Specific heat, soft steel—0.16—Meuther
 Latent heat of fusion, pig iron—Hutter
 Latent heat of fusion, steel—average value—Jetner, Richards, Brisker
 Heat in molten slag—Springorum

Thermal Balance Sheet

HEAT ABSORBED

Red. of oxides of Fe	=	18.22
Absorp. moist. of ore	=	2.21
Decomp. of limestone	=	3.46
Absorp. moist. of limestone	=	0.21
Decomp. of dolomite	=	0.67
Heat in molten slab	=	9.57
Heat added to mixer metal	=	7.88
Heat added to scrap	=	19.82

HEAT GENERATED

Oxidation of C	=	11.66×10^6
Oxidation of Mn	=	1.69×10^6
Oxidation of Si	=	5.71×10^6
Oxidation of P	=	1.35×10^6
Heat form. slag	=	1.02×10^6
Balance heat to be supplied by combustion of gases in furnace	=	40.61×10^6
Total B.t.u.	=	62.04×10^6

THERMAL EFFICIENCY OF BATH

Thermal efficiency of furnace = 17.3 per cent.
 B.t.u. in gas per pound of coal = 10,625

$$\text{Total B.t.u. to be supplied in producer gas} = \frac{40.61 \times 10^6}{0.175} =$$

$$232.06 \times 10^6 \text{ B.t.u.}$$

$$\text{Total coal burned} = 21,841 \text{ lb.}$$

THERMAL BALANCE SHEET

Heat Absorbed

THERMOCHEMICAL CHANGES

Reduction of oxides of iron:
 Heat of formation of Fe₂O₃ = 3240.
 Heat of formation of FeO = 2430

Input:

Fe₂O₃ = 7281
 FeO = 118
 Heat of formation:
 $\text{Fe}_2\text{O}_3 = 7281 \times 3240 = 23.59 \times 10^6$
 $\text{FeO} = 118 \times 2430 = 0.29 \times 10^6$

$$\text{Total} = 23.88 \times 10^6$$

Output:

$$\text{Tapping slag—FeO} = 1847 \times 2430 = 4.49 \times 10^6$$

Moisture in ore:

Total weight of ore = 10,023
 Per cent moisture = 8
 Total water = 802
 Total heat to make steam at 212°
 $802 \times 1092 = 0.88 \times 10^6$
 Specific heat of steam = $0.42 + 0.00013 \times (2800 + 212) = 0.81$
 Heat in superheat $802 \times (2800 - 212) 0.81 = 1.68 \times 10^6$

Decomposition of limestone:

Heat of formation CaCO₃ per lb. = 772 B.t.u.
 Total limestone = 6915
 Total heat required = $6915 \times 772 = 5.34 \times 10^6$
 Moisture 1.5 per cent = 104
 Total heat to make steam = $104 \times 1092 = 0.11 \times 10^6$
 Heat in superheat = $104 \times 2096 = 0.22 \times 10^6$

$$\text{Total} = 0.33 \times 10^6$$

Decomposition of improperly burned dolomite:

Total weight of dolomite = 2500 lb.
 Volatile = 15.54 per cent = 389 lb.
 Assumed 98 per cent = 381 exists as CO₂
 To drive off CO₂ = 1756 B.t.u. per lb.
 Total heat to drive off CO₂ = $1756 \times 381 = 0.67 \times 10^6$

THERMOPHYSICAL CHANGES

Hot metal = 65,000 lb. Temperature = 2474° F.
 Tapping temperature = 3080° F. includes emissivity factor
 Temperature rise (3080 — 2474) = 606° F.
 Specific Heat = 0.2
 Heat absorbed = $65,000 \times 606 \times 0.2 = 7.88 \times 10^6$
 Scrap = 35,000 lb. Temperature = 62° F.
 Melting temperature scrap = 2795° F.
 Heat required to bring to melting temperature = $35,000 \times 2733 \times 0.16 = 15.30 \times 10^6$
 Latent heat of fusion = 72 B.t.u.
 Total heat of fusion = $35,000 \times 72 = 2.52 \times 10^6$
 Heat to raise to temperature of bath = $(2080 - 2795) 35,000 \times 0.2 = 2.00 \times 10^6$
 Total heat = 19.82×10^6

Total heat in molten slag:

$$\text{Heat in tapping slag} = 11,965 \times 1066 = 12.75 \times 10^6 \text{ B.t.u.}$$

$$\text{Total heat absorbed} = 68.74 \times 10^6 \text{ B.t.u.}$$

Heat Generated

Oxidation of carbon, weight = 2666 lb.
 Heat of formation of CO from C per lb = 4374 B.t.u.
 Heat generated = $4374 \times 2667 = 11.66 \times 10^6$
 Oxidation of manganese, weight = 1115 lb.
 Heat of formation of MnO = 2984 B.t.u.
 Heat generated = $2984 \times 1115 = 3.33 \times 10^6$
 Oxidation of silicon, weight = 488 lb.
 Heat of formation of SiO₂ = 11,693 B.t.u.
 Heat generated = $11,693 \times 488 = 5.71 \times 10^6$
 Oxidation of phosphorus, weight = 129 lb.
 Heat of formation of P₂O₅ = 10,825 B.t.u.
 Heat generated = $10,825 \times 129 = 1.40 \times 10^6$
 Heat of formation of slag, weight = 11,965 lb.
 Heat of formation of slag = 98 B.t.u.
 Heat generated = $98 \times 11,965 = 1.17 \times 10^6$
 Total heat generated = 23.27×10^6 B.t.u.

Authorities for Constants Used

THERMOCHEMICAL CHANGES

Iron oxide reduction—Richards
 Decomposition of limestone—U. S. Bureau of Standards

TABLE 8.—High-manganese Iron, High-silica Ore, Furnace Charge
CHEMICAL BALANCE SHEET

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Material	Weight, in Pounds	Per Cent. C	Pounds C	Pounds CO	Per Cent. Si	Pounds Si	Per Cent. SiO ₂	Pounds SiO ₂	Per Cent. P	Pounds P	Per Cent. P ₂ O ₅	Pounds P ₂ O ₅	Per Cent. Mn	Per Cent. MnO	Pounds Mn	Per Cent. S
Basic hot metal.....	65,000	4.30	2,795		0.75	488		1,039	0.20	130			2.00		1,300	0.04
Structural steel scrap.....	35,000	0.20	70						0.01	4			0.40		140	0.04
Chapin ore (natural).....	10,023						9.29	931	0.05	5			0.13		13	
Michigan limestone.....	6,915						0.31	24	0.006							0.042
Calced dolomite.....	2,500						1.32	33	0.004							0.126
Fluorspar.....	300						1.12	3	0.004							
SiO ₂ from furnace structure.....								100								
Total entering furnace.....						488		2,130		139					1,453	
Total steel in bath.....	99,289	0.20	2,865						0.01	10			0.34		338	0.035
Tapping slag, 99.89 per cent.....	11,965		199				17.80	2,130		129	2.47	296		9.84	913	0.25
Total output.....								2,130		139					1,251	
Unaccounted for.....															-202	
Metalloids oxidized.....			2,606			488				129					1,115	

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Material	Pounds S	Per Cent. CaO	Pounds CaO	Per Cent. MgO	Pounds MgO	Per Cent. Fe	Pounds Fe	Per Cent. FeO	Pounds FeO	Per Cent. Fe ₂ O ₃	Pounds Fe ₂ O ₃	Per Cent. Al ₂ O ₃	Pounds Al ₂ O ₃	Per Cent. CaF ₂	Per Cent. Volume	Per Cent. Moisture
Basic hot metal.....	26						60,261									
Structural steel scrap.....	14						34,772									
Chapin ore (natural).....		1.60	160	2.64	265	51.76	5,188	1.18	118	72.64	7,281	1.10	110		3.15	8.00
Michigan limestone.....	3	54.60	3,776	0.88	61	0.20	14					0.30	21			1.50
Calced dolomite.....	3	48.58	1,215	32.58	815	0.38	10					1.49	37		15.54	
Fluorspar.....		2.50	8	0.38	1							1.15	3	92.53		
SiO ₂ from furnace structure.....																
Total entering furnace.....	46		5,159		1,142		100,245						171			
Total steel in bath.....	35					99.42	98,713									
Tapping slag, 99.89 per cent.....	30	43.12	5,159	9.54	1,142		1,432	15.41	1,847			1.43	171			
Total output.....	65		5,159		1,142		100,145		1,847				171			
Unaccounted for.....	+19						-100									
Metalloids oxidized.....							100									

Oxidation of C, Mn, Si, P—Richards, LeChatelier, Berthelot, Thomson
Formation of slag, calculated using Richards' values
THERMOPHYSICAL CHANGES
Specific heat, pig iron—0.1665—Oberhoffer
Specific heat, soft steel—0.16—Meuthner
Latent heat of fusion, pig iron—Hutter
Latent heat of fusion, steel—average value—Jettner, Richards, Brisker
Heat in molten slag—Springorum

Thermal Balance Sheet

HEAT ABSORBED

Red. of oxides of Fe	=	19.39
Absorp. moist. of ore	=	2.56
Decomp. of limestone	=	5.34
Absorp. moist. of limestone	=	0.33
Decomp. of dolomite	=	0.67
Heat in molten slag	=	12.75
Heat added to mixer metal	=	7.88
Heat added to scrap	=	19.82

HEAT GENERATED

Oxidation of C	=	11.66 × 10 ⁶
Oxidation of Mn	=	3.33 × 10 ⁶
Oxidation of Si	=	5.71 × 10 ⁶
Oxidation of P	=	1.40
Heat form. slag	=	1.17
Balance heat to be supplied by combustion of gases in furnace	=	45.47 × 10 ⁶
Total B.t.u.	=	68.74 × 10 ⁶

THERMAL EFFICIENCY OF BATH

Thermal efficiency of furnace = 17.3 per cent.
B.t.u. in gas per pound of coal = 10,685
Total B.t.u. to be supplied in producer gas = $\frac{45.47 \times 10^6}{0.173} = 262.83 \times 10^6$
Total coal burned = 24,737 lb.

THERMAL BALANCE SHEET
Heat Absorbed

THERMOCHEMICAL CHANGES

Reduction of oxides of iron:
Heat of formation of Fe₂O₃ = 3240
Heat of formation of FeO = 2430
Input:
Fe₂O₃ = 7291
FeO = 109
Heat of formation:
Fe₂O₃ = 729 × 3240 = 23.62 × 10⁶
FeO = 109 × 2430 = 0.26 × 10⁶
Total = 23.88 × 10⁶
Output:
Tapping slag FeO = 1213 × 2430 = 295 × 10⁶
Moisture in ore:
Total weight of ore = 9250
Per cent moisture = 8.20
Total water = 9250 × 0.082 = 759
Total heat to make steam at 212° = 759 × 1092 = 0.83 × 10⁶
Specific heat of steam = 0.42 + 0.00013 × (2800 + 212) = 0.81
Heat in superheat = 759 × (2800 - 212) 0.81 = 1.59 × 10⁶
Decomposition of limestone:
Total = 2.42 × 10⁶
Heat of formation CaCO₃ per lb. = 772 B.t.u.
Total limestone = 4620
Total heat required = 4620 × 772 = 3.57 × 10⁶
Moisture 1.5 per cent = 4620 × 0.015 = 69.3
Total heat to make steam = 69.3 × 1092 = 0.08 × 10⁶
Heat in superheat = 69.3 × 2096 = 0.15 × 10⁶
Total = 0.23 × 10⁶
Decomposition of improperly burned dolomite:
Total weight of dolomite = 2500 lb.
Volatile = 15.54 per cent = 389 lb.
Assumed 98 per cent = 381 exists as CO₂
To drive off CO₂ = 1756 B.t.u. per lb.
Total heat to drive off CO₂ = 1756 × 381 = 0.67 × 10⁶

THERMOPHYSICAL CHANGES

Hot metal = 65,000 lb. Temperature = 2474° F.
 Tapping temperature = 3080° F. includes emissivity factor
 Temperature rise (3080 — 2474) = 606° F.
 Specific Heat = 0.2
 Heat absorbed = 65,000 × 606 × 0.2 = 7.88 × 10⁶
 Scrap = 35,000 lb. Temperature = 62° F.
 Melting temperature scrap = 2795° F.
 Heat required to bring to melting temperature = 35,000 × 2733
 × 0.16 = 15.30 × 10⁶
 Latent heat of fusion = 72 B.t.u.
 Total heat of fusion = 35,000 × 72 = 2.52 × 10⁶
 Heat to raise to temperature of bath = (3080 — 2795) 35,000 ×
 0.2 = 2.00 × 10⁶
 Total heat = 19.82 × 10⁶
 Total heat in molten slag:
 Heat in tapping slag = 9254 × 1066 = 9.86 × 10⁶ B.t.u.
 Total heat absorbed = 65.38 × 10⁶ B.t.u.

Heat Generated

Oxidation of carbon, weight = 2665 lb.
 Heat of formation of CO from C per lb = 4374 B.t.u.
 Heat generated = 4374 × 2665 = 11.66 × 10⁶
 Oxidation of manganese, weight = 1047 lb.
 Heat of formation of MnO = 2984 B.t.u.
 Heat generated = 2984 × 1047 = 3.12 × 10⁶
 Oxidation of silicon, weight = 488 lb.
 Heat of formation of SiO₂ = 11,693 B.t.u.
 Heat generated = 11,693 × 488 = 5.71 × 10⁶
 Oxidation of phosphorus, weight = 126 lb.
 Heat of formation of P₂O₅ = 10,825 B.t.u.
 Heat generated = 10,825 × 126 = 1.36 × 10⁶
 Heat of formation of slag, weight = 9254 lb.
 Heat of formation of slag = 108 B.t.u.
 Heat generated = 108 × 9254 = 1.00 × 10⁶
 Total heat generated = 22.85 × 10⁶ B.t.u.

Authorities for Constants Used

THERMOCHEMICAL CHANGES

Iron oxide reduction—Richards
 Decomposition of limestone—U. S. Bureau of Standards

Oxidation of C, Mn, Si, P—Richards, LeChatelier, Berthelot, Thomson

Formation of slag, calculated using Richards' values

THERMOPHYSICAL CHANGES

Specific heat, pig iron—0.1665—Oberhoffer
 Specific heat, soft steel—0.16—Meuthner
 Latent heat of fusion, pig iron—Hutter
 Latent heat of fusion, steel—average value—Jetner, Richards, Brisker
 Heat in molten slag—Springorum

Thermal Balance Sheet

HEAT ABSORBED

Red. of oxides of Fe	=	20.93
Absorp. moist. of ore	=	2.42
Decomp. of limestone	=	3.57
Absorp. moist. of limestone	=	0.23
Decomp. of dolomite	=	0.67
Heat in molten slag	=	9.86
Heat added to mixer metal	=	7.88
Heat added to scrap	=	19.82

HEAT GENERATED

Oxidation of C	=	11.66 × 10 ⁶
Oxidation of Mn	=	3.12 × 10 ⁶
Oxidation of Si	=	5.71 × 10 ⁶
Oxidation of P	=	1.36 × 10 ⁶
Heat form. slag	=	1.00 × 10 ⁶
Balance heat to be supplied by combustion of gases in furnace	=	42.53 × 10 ⁶
Total B.t.u.	=	65.38 × 10 ⁶

THERMAL EFFICIENCY OF BATH

Thermal efficiency of furnace = 17.3 per cent.
 B.t.u. in gas per pound of coal = 10,625
 Total B.t.u. to be supplied in producer gas = 245.83 × 10⁶
 Total coal burned = 23,137 lb.

(To be concluded.)

TABLE 9.—High-manganese Iron, Low-silica Ore, Furnace Charge

CHEMICAL BALANCE SHEET

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Material	Weight in Pounds	Per Cent. C	Pounds C	Pounds CO	Per Cent. Si	Pounds Si	Per Cent. SiO ₂	Pounds SiO ₂	Per Cent. P	Pounds P	Per Cent. P ₂ O ₅	Pounds P ₂ O ₅	Per Cent. Mn	Per Cent. MnO	Pounds Mn	Per Cent. S
Basic hot metal.....	65,000	4.30	2,795		0.75	488		1,039	0.20	130			2.00		1,300	0.04
Structural steel scrap	35,000	0.20	70						0.01	4			0.40		140	0.04
Low SiO ₂ ore (natural).....	9,250						4.62	427	0.017	2			0.07		6	0.006
Michigan limestone.....	4,620						0.34	16	0.006							0.042
Calcined dolomite.....	2,500						1.32	33	0.004							0.126
Fluorspar.....	300						1.12	8	0.004							
SiO ₂ from furnace structure.....								100								
Total entering furnace.....			2,865			488		1,618		136			0.40		1,446	
Total steel in bath.....	99,849	0.20	200						0.01	10					399	0.035
Tapping slag, 100.19 per cent.....	9,254						17.48	1,618		126	3.12	289		11.72	841	0.25
Total output.....			2,865					1,618		136					1,240	
Unaccounted for.....															206	
Metalloids oxidised.....			2,665			488				126					1,047	

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Material	Pounds S	Per Cent. CaO	Pounds CaO	Per Cent. MgO	Pounds MgO	Per Cent. Fe	Pounds Fe	Per Cent. FeO	Pounds FeO	Per Cent. Fe ₂ O ₃	Pounds Fe ₂ O ₃	Per Cent. Al ₂ O ₃	Pounds Al ₂ O ₃	Per Cent. CaF ₂	Per Cent. Volume	Per Cent. Moisture
Basic hot metal.....	26						60,261									
Structural steel scrap.....	14						34,772									
Low SiO ₂ ore (natural).....		0.96	89	2.12	196	56.09	5,188	1.18	109	78.82	7,291	1.10	102		1.68	8.20
Michigan limestone.....	2	54.60	2,523	0.88	41	0.20	9					0.30	14			1.50
Calcined dolomite.....	5	48.58	1,215	32.58	815	0.38	10					1.49	37		15.54	
Fluorspar.....		2.50	8	0.38	1							1.15	3	92.53		
SiO ₂ from furnace structure.....																
Total entering furnace.....	47		3,835		1,053		100,240						156			
Total steel in bath.....	35						99,200									
Tapping slag, 100.19 per cent.....	23	41.44	3,835	11.38	1,053		940	13.11	1,213			1.69	156			
Total output.....	58		3,835		1,053		100,140						156			
Unaccounted for.....	+11						-100									
Metalloids oxidised.....							100									

Significance of the Hearth¹

A Continuation of the Bureau of Mines Report of Data Secured
from Experimental Blast Furnace

By P. H. ROYSTER², T. L. JOSEPH³ and S. P. KINNEY⁴

THE process of reduction of iron ore in the blast furnace has been discussed by the writers,⁵ who illustrated their discussion with data collected during the operation of an experimental furnace by the Bureau of Mines at its Minneapolis station. It was pointed out that the so-called "bosh gas", formed at the nose of the tuyere, a 35-65 mixture of carbon monoxide and nitrogen, has two functions to perform as it is forced upward through the furnace shaft. The first is a chemical one of reducing the ore to the metallic state, while the second is a physical one of heating descending solids. The purpose of this present paper is to present experimental data bearing on the temperatures attained by the slag, the metal, and the coke, in the bottom of the furnace. Part of the data was collected at industrial blast-furnace plants⁶, and part during the operation of the experimental furnace.

The problem of preheating the descending charge, and particularly of melting the slag and the metal, has attracted more attention among metallurgists and furnace-men than has the chemical process of ore reduction. It happens that no difficulty would be experienced in satisfying both these requirements if it were required only that the furnace make merchantable pig iron. Actually it is necessary for the furnace to make not only pig iron, but money, and this financial aspect of the problem introduces two economic requirements — the production of a maximum tonnage by each furnace unit, and the realization of a minimum consumption of fuel for each ton of metal made. To comply with these economic demands, heavy burdening and fast driving are required. It is not possible, however, to go too far in this direction or the furnace will become involved in operating difficulties. The first important indication of the presence of such difficulties is the appearance of high-sulphur iron. If, for any reason, the production of such off-grade metal is ignored, and the overburdening or over-driving be carried further, a black iron-bearing cinder will result. Such a condition causes a loss both of quality and quantity in the iron product, and, though possibly a frequent happening in times past, is today distinctly a rare occurrence.

¹Second of the series. Published by permission of the Director, U. S. Bureau of Mines. This work was done in co-operation with the University of Minnesota.

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⁵Royster, P. H., Joseph, T. L., and Kinney, S. P., Reduction of iron ore in the blast furnace: *Blast Furnace and Steel Plant*, vol. 12, 1924, pp. 35-37.

⁶The Bureau of Mines wishes to acknowledge the helpful co-operation of the following companies in the collection of these data: Bethlehem Steel, Brier Hill, Buffalo Union, Colorado Fuel & Iron, Jones & Laughlin, Illinois Steel, McKinney Steel, Lackawanna, National Tube, Rogers Brown, Republic Iron & Steel, Wharton, Wickwire, and Youngstown Sheet & Tube Co.

The practical elimination of such periods of poor operation is often attributed to an improvement in the theory and practice of furnace operation, but it should not be forgotten that the present general custom of promptly reporting the analysis of each cast serves to warn the operator of the approach of the phenomenon, and measures are almost always taken temporarily to let the desire for low coke consumption and large tonnage go by the boards, and to "straighten the furnace up" as quickly as possible by suitable changing of the burden, the wind blown, and the blast temperature, or some combination of these. The furnace-man of the past, not having the help of such continuous analysis of the sulphur content of the iron

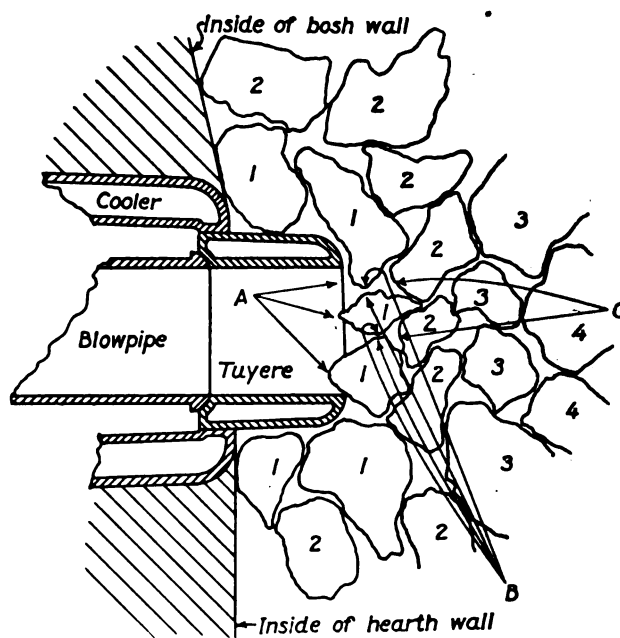


FIG. 1—Diagram showing coke at tuyere.

made, was not forewarned of impending trouble to the extent the operator is today. It is possible, therefore, that the adoption of "chemical control" of the furnace will explain or help explain the general elimination of these operating difficulties.

Hearth Temperature.

The writers have often asked themselves, as the reader may be asking himself, the obvious question, "What has this to do with hearth temperature?" The equally obvious answer to such a question is, "Measure the hearth temperature and see." Although much has been said and written about the cause and the significance of "hot iron" and "cold iron" in blast-furnace operation, few seem to have made an effort even to measure the temperature of the metal tapped from the blast furnace, much less to correlate such measurements with the various probable and fairly obvious theories of metal temperature.

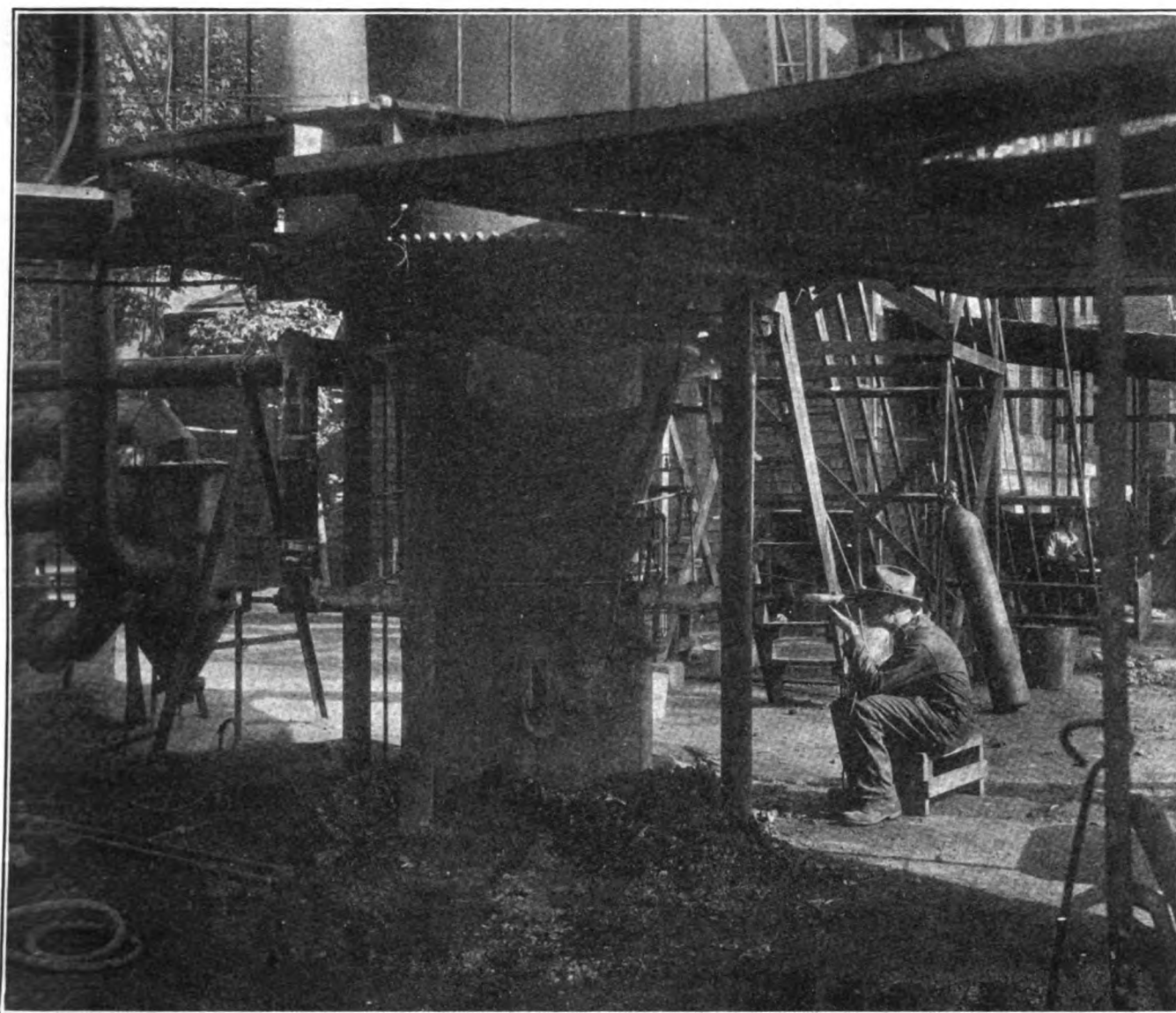


FIG. 2—View of bosh and hearth of experimental furnace.

The first systematic attempt to measure hearth temperatures to be found in technical literature seems to have appeared⁷ in 1919. Temperature measurements had been given in 1918, in Bureau of Mines' reports⁸ on the production of ferro-manganese and spiegeleisen, but figures relating to manganese alloy furnaces are not precisely in order in this discussion. Temperature observations at single furnace plants had

⁷Royster, P. H., and Joseph, T. L., *Pyrometry in blast-furnace work*: A. I. M. & M. E. volume on Pyrometry, 1920, pp. 544-558. Discussion on pp. 558-567.

⁸(a) Royster, P. H., Bureau of Mines War Minerals Investigation Series No. 5 and 6, 1918.

(b) Weld, C. M., and others, *Manganese: uses, preparation, mining costs, manufacture of ferro-alloys*: Bull. 173, Bureau of Mines, 1920, 209 pp.

⁹(a) Linville, C. P., *Combustion temperature of carbon and its relation to blast-furnace operation*: Trans. A. I. M. E., vol. 41, 1910, pp. 268-279.

(b) Backman, F. E., *The use of titaniferous ore in the blast furnace*: Year Book Amer. Iron & Steel Inst., 1914, pp. 370-419 (Table III gives the temperature readings made by J. F. Cullum of the Bureau of Mines.)

(c) Johnson, J. E., Jr., *Operation of the blast furnace*: *Met. & Chem. Eng.*, vol. 14, 1916, pp. 363-372.

(d) Feild, A. L., *Viscosity of blast-furnace slag*: Trans. Faraday Society, vol. 13, 1917, part 1, pp. 3-35.

previously been measured by Linville⁹, Cullum (Backman), Johnson, and Feild, but the figures given by these writers are fragmentary, and were taken only from isolated furnace plants, and it seems difficult to draw comparative relationships between them. The data given by Royster and Joseph covered 20 modern blast-furnace plants, taken as nearly as possible under the same conditions. It has been said in criticism of their work that American furnace practice cannot properly be covered by measurements at only 20 furnaces, so their work was continued until 50 furnaces had been investigated. The addition of data from 30 other furnaces has not had the effect of changing appreciably either the average value for the three kinds of hearth temperatures measured by them or the relationship between these three. To some extent, the fact that a study of the first 20 furnaces gives the same answer as does a consideration of all 50 furnaces, tends to inspire confidence in the conclusions drawn from both.

Three Hearth Temperatures.

Earlier writers on the metallurgy of iron had to content themselves with the theorem implied or expressed that there was a "hearth temperature", some

unknown but more or less definite temperature obtaining generally in the crucible of the furnace. Johnson¹⁰ seems to have been the first to point out directly that the molten bath of slag and metal was, according to his estimate, about 200 deg. C. colder than the temperature in the combustion zone. He found the combustion zone to be about 1650 deg. C., and the metal and slag to average 1450 or 1550 deg. C. It does not appear that he considered the possibility of these two fluids being at different temperatures. Three temperatures in the furnace hearth have been reported in the Bureau of Mines papers cited above, and were termed "metal temperature", "slag temperature", and "tuyere temperature". In a recent investigation, Perrott and Kinney¹¹ have studied the position of the "combustion zone" in 11 furnaces, and have shown (1) that combustion takes place essentially in the same portion in every furnace; and (2), that this is not a "zone", but a number of "spheres", one at the nose of each tuyere. A study of the gas analyses given by Perrott and Kinney makes the so-called "tuyere temperatures" of Royster and Joseph somewhat doubtful. Assuming that the number of papers¹² inspired by Perrott and Kinney's report indicate a general interest in the phenomenon of how the coke burns at the tuyeres, a brief description of what exists at the nose of the tuyere may not be out of place.

Coke Temperature at the Tuyere Nose.

Fig. 1 is a somewhat fanciful diagram of a bed of coke resting at the nose of a tuyere. Something similar to this exists in actual furnace operation, provided first that the jet velocity of the blast is not so great that the coke lumps will be blown away from the tuyere, and second that the coke lumps in the bosh just above the tuyeres are free to promptly replace the coke as it is burned near the tuyeres. In these circumstances there are three points in the fuel bed which are subject to such different physical and chemical conditions that it is well to distinguish them from each other.

The coke lumps marked 1 are called for convenience the first layer; those marked 2, the second layer, etc. Initial contact between blast and fuel takes place at position marked A. That portion of the gas stream involved in combustion with first layer lumps flows from A to B. The gas arriving at B is no longer atmospheric air at blast temperature, but is preheated during its travel from A to B by the reception of so much of the heat as is generated in the production of the carbon dioxide it contains. Perrott and Kinney's gas analyses throw little light on the composition of

the gas blown across the coke at the point B, because the sampling tube used by them was too large, compared with the size of the coke lumps, to obtain a sample. The gas jets through the irregular cracks between the first layer lumps and impinges on second layer lumps at C.

The process here is slightly analogous to the case of a multi-stage impulse turbine in which steam jets through the first-stage nozzles, strikes the first-stage buckets, is discharged with an altered pressure, temperature, superheat, entropy, and total heat, and then jets through the second-stage nozzles and impinges on the second-stage buckets, with another change in its physical properties. The combustion problem is the harder to study, because the size and shape of the coke lumps are irregular and vary, and in addition to the gas changing in physical properties, its chemical composition is also changed due to the process of combustion that is going on. Gas analyses show that combustion is practically complete in about 40 inches. The layers of coke involved in combustion will probably average nine, while seven to eleven would probably cover the number of active layers in the combustion spheres.

Measurements of Temperature in the Combustion Spheres.

If irregular solids are thrown into a pile, it is known that the front side of the top layer is visible, and that portions of the front side of the second layer are visible through the interstices in the first layer. The third layer is never visible except through some freak of chance. In looking through a tuyere, positions A, B, and C can generally be seen and temperatures measured with a disappearing filament pyrometer. In the bureau's experimental furnace, conditions were favorable to such pyrometry; the selection of the jet velocity, furnace lines, size and number of tuyeres, and size of the coke lumps having been considered in the design to ensure that the coke would lie at the face of the tuyeres in the manner shown in R, Fig. 1. A photograph of the bosh and hearth of the experimental furnace is shown in Fig. 2, an observer being seen in position to read tuyere temperatures.

Effect of Blast Temperature on Tuyere Temperature.

Certain operating features of the Bureau's thirty-fifth campaign with the experimental furnace were given in the writers' two previous papers in this journal. The lines of the furnace are shown¹³ in Fig. 2. This 20-inch hearth furnace was blown-in on cold wind at its full working volume of 300 cubic feet per minute. The initial coke blank was so small that the first slag appeared at the end of 60 minutes. The composition of top gas was essentially bosh gas about 20 minutes after igniting the fuel. The furnace was charged with 120 pounds of nut coke and 160 pounds of manganiferous slag from previous runs. The slag was practically iron-free, and since no flux was charged, the furnace operated making slag but no metal. About 90 minutes after being blown-in, the temperature at position C varied from 1770 to 1707 deg. C. Cold blast was continued for 10 hours, and sufficient readings were taken to give reliable average temperatures. Hot blast was then applied without changing any other operating condition. Table I gives,

¹³Royster, P. H., Joseph, T. L., and Kinney, S. P., work cited.

¹⁰Johnson, J. E., Jr., Blast furnace construction, 1917, p. 233+.

¹¹Perrott, G. St. J., and Kinney, S. P., Combustion of coke in the blast-furnace hearth: Trans. A. I. M. & M. E., vol. 69, 1923, p. 526.

¹²(a) Sherman, Ralph A., and Kinney, S. P., Combustibility of blast-furnace coke: Paper read before Eastern States Blast Furnace and Coke Oven Association, South Bethlehem, Pa., May 23, 1923; reprinted in *Iron-Age*, vol. III, 1923, pp. 1839-1844.

(b) Fieldner, A. C., Combustibility of coke; Paper read at meeting of Amer. Inst. Chem. Eng., Washington, D. C., Dec. 5, 1923; reprinted in *Chem. & Met. Eng.*, vol. 29, 1923, pp. 1052-1057.

(c) Perrott, G. St. J., and Fieldner, A. C., Properties of metallurgical coke: Proc. Amer. Soc. Test. Mats., vol. 23, 1923, pp. 475-493. Discussion pp. 494-500.

(d) Royster, P. H., and Joseph, T. L.; The effect of coke combustibility on stock descent in the blast furnace: Paper read at Feb., 1924, meeting of A. I. M. & M. E. at New York, preprint No. 1307-S.

for convenient comparison, the average pyrometer readings.

TABLE 1—Pyrometer readings during furnace runs with cold and hot blast (°C.).

Tuyere blast	No. 1 Run			No. 2 Run		
	Cold blast	Hot blast	Difference	Cold blast	Hot blast	Difference
Temperature						
Point A	1362	1531	169	1383	1575	192
Point B	1431	1617	186	1469	1630	161
Point C	1601	1732	131	1631	1749	118
Mean			162			157

The effect of changing the blast temperature from 68 to 692 deg. F. (an increase of 346 deg. C.), is accompanied by an increase of 160 C. in coke temperature at positions A, B, and C. This result could be roughly stated as the combustion temperature rises one deg. for every two deg. increase in blast temperature. This increase is little better than half the theoretical change calculated by the usual assumptions made in discussing the thermal principles of the blast furnace. Nearly 400 observations were averaged in computing Table I, all taken with the same pyrometer but by three observers.¹⁴ This seems the only evidence of a quantitative sort tending to show that when all other factors are held constant, hot blast produces a higher combustion temperature than does cold blast. It will be shown below that proof of such a relation from similar measurements at industrial plants is not so satisfactory.

A, B, and C Tuyere Temperatures.

The apparent rise of 160 deg. C. in temperature, due to increasing the blast temperature to 692 deg. F., is big enough to discuss and too big to ignore. The differences in temperature between the characteristic points A, B, and C are of the same order of magnitude, however. For example, readings at C average 215 deg. C. hotter than those at A; the difference is 242 deg. C. for cold blast and 188 deg. for hot blast. The probable average distance between A and C, with the nut coke used, was not much greater than one inch—possibly less. A rise in temperature of 200 deg. C. per inch would indicate a rise of 2000 deg. C. in 10 inches, the radius of the hearth. Since the temperature at the point A is greater than 1300 deg. and less than 1600 deg. C., this rate of increase in temperature, if maintained, would predict 3300 to 3600 deg. C. at the center of the 20-inch furnace.

In taking observations at industrial plants, conditions for such observations are much worse. In fact, at many plants a re-design of the tuyeres and peep-sights, a change in wind, and alteration in furnace line to prevent bosh hanging, would be necessary to permit any sure distinction between these kinds of tuyere temperatures. It is not so difficult even with a tuyere of high jet velocity, where the coke lumps dart into and out of the field of vision, leaving only a few seconds for setting the pyrometer, to eliminate point A from the headings as much as possible. The most serious source of error is the presence of a flame

at the tuyeres, when the first layer lumps are driven by the blast a foot or so from the tuyere nose. The apparent temperature of the coke bed, as viewed through the flame, is too low, due to the absorption of light in the flame itself. Fine solid particles, either from the blast (dirty stoves) or stirred up in the coke bed itself (soft coke), accentuate the difficulties caused by the flame. In the readings at industrial plants, those taken through a flame were discarded. The "tuyere temperature," attributed by the writers to industrial furnaces, is probably an average of B and C readings. The experimental blast-furnace observations are easily interpreted. In the case of both the B and the C positions, the effect of hot blast is about the same; hence, the effect on the average of B and C should be the same. It is logical therefore to plot tuyere temperatures against blast temperatures, with the hope of finding an upward sloping curve. This has been done in Fig. 3, but the slope of the curve is apparently downward.¹⁵

Effect of Blast Temperature on Slag Temperature.

Johnson¹⁶ has suggested that at whichever point the slag becomes fluid enough to be "free-running," it drops quickly into the slag bath without further rise of temperature. Such a statement would make the temperature depend on its temperature-fluidity characteristics, and be more or less independent of blast temperature or of tuyere temperature. In the case of large furnace operation this seems to be true. According to Table 2, illustrated graphically in Fig. 3, the effect of blast temperature on slag temperature is small, if any. In the same way Table 3 and Fig. 4 show observed slag temperature to be practically independent of tuyere temperature. It might be possible (the attempt seems not to have been made even by Johnson) to extend this free-running theory to explain why the observed metal temperatures, also plotted in Figs. 3 and 4, are to the same extent unaffected by blast temperature or by the temperature of the combustion zone.

TABLE II.
Furnaces grouped in order of increasing blast temperature.

Temperature of	Groups				Average
	I	II	III	IV	
Blast, deg. F.....	865	977	1057	1233	1033
Metal, deg. C.....	462	525	569	667	555
Tuyere, deg. C.....	1761	1684	1715	1672	1708
Slag, deg. C.....	1527	1523	1523	1531	1526
Metal, deg. C.....	1476	1474	1467	1471	1472

TABLE III.
Furnaces grouped in order of tuyere temperatures (Deg. C.).

Temperature of	Groups				Average
	V	VI	VII	VIII	
Tuyere	1619	1678	1737	1798	1708
Slag	1515	1526	1528	1535	1526
Metal	1462	1470	1477	1479	1472
Difference between slag and metal temperatures	53	56	51	56	54

¹⁴The writers wish to acknowledge here the assistance of F. B. Foley, metallurgist of Bureau of Mines, now at its Mississippi Valley Experiment Station, Rolla, Missouri, in conducting this and many other experimental blast-furnace tests.

¹⁵Johnson, J. E., Jr., Principles, operation and products of the blast-furnace; 1918, McGraw-Hill Book Company, New York.
¹⁶Johnson, J. E., Jr., work cited.

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The following data from the Bureau's experimental furnace records, during the period of operation on cold and on hot blast,¹⁷ offer a stronger confirmation of the approximate truth of this free-running theorem. During the time the furnace was at a steady state on cold blast, slag was flushed from the hearth 16 times, while under the average blast temperature of 692 deg. F.,

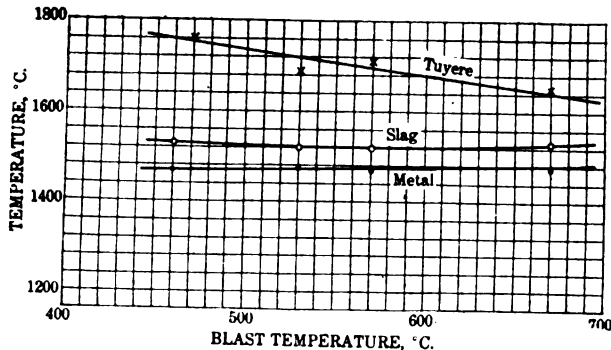


FIG. 3—Curves showing blast temperature and slag temperature.

32 flushes were made. During each period, slag readings were taken for six flushes. These observations give the following average temperatures: with cold blast, 1382 deg. C., and with hot blast, 1360 deg. C. These two temperatures are identical within the limits of accuracy attained. This experiment shows that, although hot blast increased the tuyere temperature 160 deg. C., its effect on slag temperature could not be detected.

Hearth Temperatures in the Experimental Furnace.

Enough has been said in regard to the significance of the various temperatures that can be measured in the tuyere zone and in the crucible of a blast furnace to make intelligible a comparison between industrial furnace units and the Bureau's 20-inch furnace. When this furnace was operated on the burden, under the conditions and with the results described in the writers' two other papers in this journal,¹⁸ the average temperatures observed are those given in item 10 of Table IV following:

TABLE IV.
Comparison of hearth temperatures with various practices.

Item	Furnace	— Temperature, Deg. C. —		
		Tuyeres	Slag	Metal
1	Pig iron ¹	1711	1509	1466
2	Pig iron ²	1708	1526	1472
3	Foundry iron	1748	1553	1493
4	Bessemer iron	1733	1513	1466
5	Basic iron	1669	1522	1468
6	Charcoal ³	1669	1451	1415
7	Manganese alloy ⁴	1573	1427	1389
8	Spiegeleisen	1597	1427	1392
9	Ferro-manganese	1550	1426	1386
10	Experimental furnace	1647	1529	1396

¹Average of 20 furnaces. Royster, P. H., and Joseph, T. L., Pyrometry in blast-furnace work: A. I. M. & M. E. volume on Pyrometry, 1920. Also see *Blast Furnace and Steel Plant*, vol. 7, 1919, pp. 556-560.

²Mean of 43 furnaces given in Tables II and III. Items 3, 4, and 5 divide the furnaces according to the grade of iron made.

³Joseph, T. L., Temperatures in charcoal blast furnaces (unpublished paper).

⁴See Bureau of Mines Bull. 173, p. 141. Work cited.

¹⁷The tuyere temperatures during this test are given in Table I.

¹⁸Royster, P. H., Joseph, T. L., and Kinney, S. P., work cited.

For the sake of comparison, similar temperatures from industrial furnaces operating under a variety of practices are given in items 1 to 9. Since the experimental furnace was making basic iron, it is more appropriate to compare the readings with those in item 5. It will be seen that the bureau's slag is slightly hotter and the tuyeres are colder than the average. Of the 26 furnaces grouped under item 5, however, nine have colder tuyeres and 13 have colder slags than are found in item 10. It can hardly be said that any real difference exists between the large units and the experimental furnace.

The metal temperature in item 10 is, however, undeniably cold. The figures are not as reliable as the remainder of the data because the small amount of metal tapped at each cast (from 300 to 400 pounds), gave only a short time for temperature readings. It is doubtful, however, if experimental error will completely explain the difference.

Metallurgists have generally agreed that it is possible in a 500-ton furnace to realize a greater intensity of heat than is possible with so small a unit as the bureau's furnace. The data presented here shows definitely, however, that any temperature differences due to furnace size are negligibly small, if they exist at all. This is a most encouraging feature in the development of experimental furnace research. It brings the

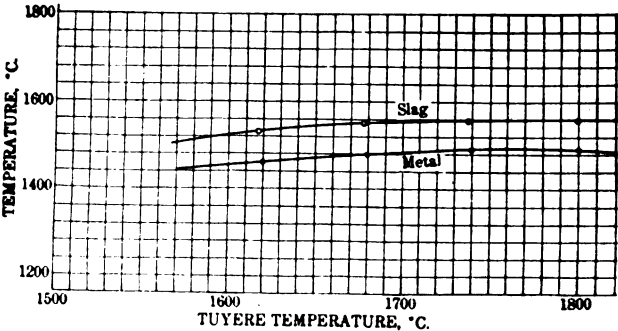


FIG. 4—Curves show slag and tuyere temperatures.

state of iron metallurgy a step nearer the point where the phrase, "it has been shown", can be substituted for "metallurgists have generally agreed". From the data in this paper a number of questions relating to hearth temperatures can be answered in this manner. For one thing, it is reasonably obvious that the significance of hearth temperatures is not so simple as metallurgists have generally agreed.

French Iron and Steel in 1923

Production of iron and steel in France during 1923 was greater than during the preceding year, according to cabled advice to the Commerce Department from Acting Commercial Attache J. F. Butler, Paris. Pig iron output totaled 5,299,000 metric tons and steel 4,977,000 tons in 1923, compared with 5,128,000 tons and 4,471,000 tons, respectively, in 1922.

The iron and steel market is disorganized due to exchange, doubt regarding the outcome of the financial discussions in the Chamber of Deputies, and manufacturers' perplexity regarding future prices of coke. The agreements under which the Societe des Consummateurs de Coke des Hauts Fourneaux, popularly known as the "Scof," distributed supplies of coke to the French metallurgical plants, came to an end on January 31.

SHEET AND TIN PLATE

Pair Heating

Further Description of a Heating Furnace of New Design, and
Employing Two-Stage Combustion

By WILLIAM C. BUELL, JR.*

PART II

A Furnace Test.

In July, 1923, a test made of the furnace operation and from the data secured a number of interesting studies have been made. The tests were taken on five consecutive days, and although data was taken over the first day's run, these figures are not included in any of the totals as it was considered only as an opportunity to try out different adjustments and conditions.

A balance sheet on the basis of the total test and the best day is given as Table I.

Under item "A", sub-item II and under item "B", sub-item VII is shown "in coal unburned". Due to single turn operation, it was as explained before, it was necessary to rapidly feed a considerable weight of fuel (over 1,000 lbs.) to form the bed of the fire, and this quantity (approximately) remained unburned when the furnace was shut down at the end of the day. As this loss was characteristic of local conditions within the plant, it is shown as a separate item, not chargeable to furnace operating losses as it would nearly be absent in continuous operation.

TABLE I — BALANCE SHEET.

Semi-Producer Recuperative Furnace.

a. Pounds coal per ton steel heated; b, Pounds coal per hour; C, Per cent of AA (total).

A. Heat Input with Source:				Average 4 Days	Average Best Day
1. In coal burned.....	a	180.0 lbs.		120.0 lbs.	
	b	214.0 "		207.0 "	
	c	78.2%		74.3%	
2. In coal unburned.....	a	51.0 lbs.		31.0 lbs.	
	b	61.0 "		54.0 "	
	c	20.8%		19.4%	
3. In blower steam.....	a	0.5 lbs.		0.4 lbs.	
	b	0.6 "		0.6 "	
	c	0.2%		0.2%	
4. In blower air.....	a	0.8 lbs.		0.5 lbs.	
	b	1.0 "		0.8 "	
	c	0.4%		0.3%	
5. In hot blast.....	a	14.4 lbs.		9.4 lbs.	
	b	17.3 "		16.2 "	
	c	5.8%		5.8%	
AA. Total Heat Input.....	a	245.0 lbs.		161.8 lbs.	
	b	293.7 "		278.6 "	
	c	100.0%		100.0%	
B. Losses Not Chargeable to Furnace:					
6. By water vapor in air..	a	0.6 lbs.		0.3 lbs.	
	b	0.7 "		0.5 "	
	c	0.2%		0.2%	

*Consulting Engineer, Pittsburgh, Pa.

7. In coal unburned.....	a	51.0 lbs.	31.0 lbs.
	b	61.0 "	54.0 "
	c	20.8%	19.4%
BB. Total Losses N. C. to F....	a	51.6 lbs.	31.3 lbs.
	b	61.0 "	54.0 "
	c	21.9%	19.6%
C. Operating Losses Chargeable to Furnace:			
8. Radiation loss semi-pro- ducer	a	8.9 lbs.	5.9 lbs.
	b	10.7 "	10.2 "
	c	3.6%	3.6%
9. Radiation loss furnace chamber	a	85.5 lbs.	40.0 lbs.
	b	102.0 "	69.0 "
	c	34.7%	24.8%
10. Radiation loss flue and recuperator	a	18.8 lbs.	14.6 lbs.
	b	22.6 "	25.1 "
	c	7.8%	9.0%
11. In gas leaving recuper- ator	a	137.0 lbs.	17.5 lbs.
	b	29.4 "	30.2 "
	c	10.8%	10.8%
CC. Total Losses C. to F.....	a	137.0 lbs.	78.0 lbs.
	b	164.7 "	135.5 "
	c	56.1%	48.2%
D. Operating Efficiencies:			
Gross DD/AA			
12. To metal	a	43.4 lbs.	44.0 lbs.
	b	52.1 "	75.8 "
	c	17.7%	27.2%
13. To hot blast.....	a	12.7 lbs.	8.0 lbs.
	b	15.2 "	13.8 "
	c	5.2%	5.2%
DD. Gross Efficiency — Heat to metal and air by transfer			
	a	56.1 lbs.	52.0 lbs.
	b	67.3 "	89.6 "
	c	22.9%	32.4%
Net DD/(AA—BB)			
12. To metal	a	43.4 lbs.	44.0 lbs.
	b	52.1 "	75.8 "
	c	21.6%	33.6%
13. To hot blast.....	a	12.7 lbs.	8.0 lbs.
	b	15.2 "	13.8 "
	c	6.3%	6.4%
D'D' Net Efficiency — Heat to metal and air by transfer			
	a	56.1 lbs.	52.0 lbs.
	b	67.3 "	89.6 "
	c	28.9%	40.0%

TABLE II — COMPARATIVE EFFICIENCIES.

Note: The symbols under each grouping represent the derivation as taken from Table I.

	Average 4 Days	Average Best Day
Semi-Producer Furnace Recuperator:		
Gross DD/AA	22.9%	32.4%
Net D'D'/(AA—BB)	28.9%	40.0%
Furnace only:		
12 / AA — (BB + 8)	23.5%	35.5%
Furnace and Recuperator:		
DD / AA — (BB + 8)	30.3%	41.8%
Recuperator only	22.6%	20.0%

In the balance sheet, Table I, it should be especially noted that all calorific values used are the "low" value.

Fuel Cost—Bolt Making.

Naturally the question will be asked as to what all the foregoing has to do with "pair" furnaces. It will first be necessary to make a comparative analysis of the improvements and economies that this furnace has shown over existing methods in the manufacture of bolts.

On a basis of 231 pounds of coal per ton (A1+A2 Table I) the cost of operation was as follows:

TABLE III — COST OF OPERATING

Coal—231 lbs. at \$3.00 del.....	\$0.36
Electric Power—4 Kw. at 1.5c / Kwh.....	.06
Steam—69 lbs. at \$1.50 / M lbs.....	.103
Firing labor	.20
Total	\$0.623

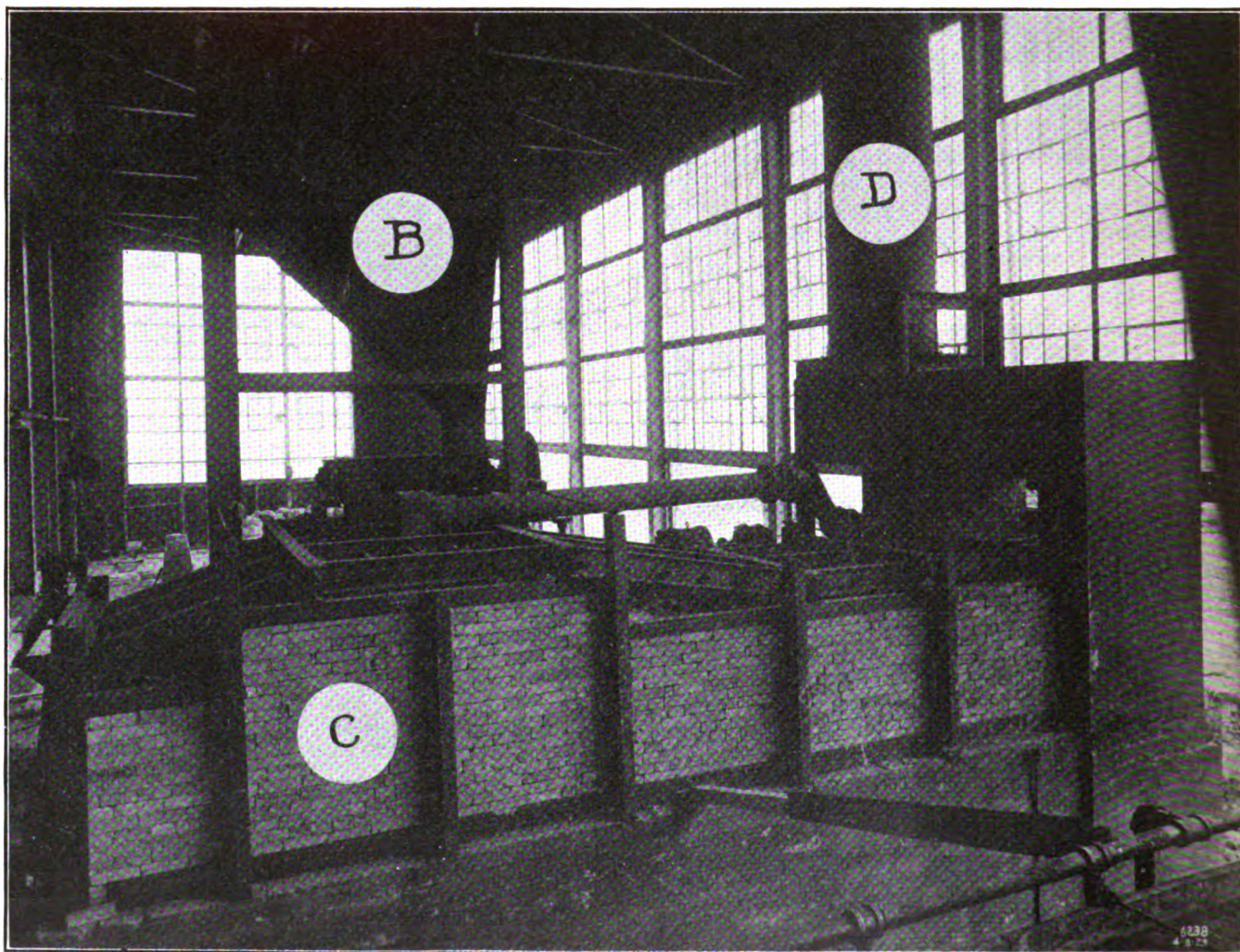
On a basis of the "Best Day" rate of 151 pounds of coal per ton the foregoing cost would vary directly with the coal rate and $(0.623 \times 161) / 231 = \0.364 per ton of steel heated.

Against the above the manufacturers of bolts claim that with good practice they require about 25 gallons of fuel oil or 4,000 cubic feet of natural gas per ton of bolt stock heated. With oil at 6c per gallon and gas at 45c per thousand the cost for fuel is \$1.50 and \$1.80 without and firing costs included.

The author was fortunate to secure a few days ago, figures on the same work using pulverized coal, and from one of the plants that is widely quoted as having excellent practice. This figure is given as \$1.60 per ton of metal, with coal at \$3.00 delivered.

(To be Continued)

Republic Iron & Steel Company is installing a Brassert washer at their No. 4 furnace. This will make the total of three Brassert washers installed at the Hazleton plant.



View showing top of furnace, with elevator, bin and piping arrangement.

Gas Producer Practice

By **WALDEMAR DYRSSEN***

PART III

Temperature of the Gas.

It has long been known that the temperature of the gas has a marked bearing on the efficiency of gasification and the quality of the gas made. It is generally agreed that a low temperature gas is the best. A few theoretical considerations confirm this in a most striking manner. The sensible heat in the gas produced by the gasification of carbon by the blast is given up in its upward travel through the producer, as follows:

1. The carbon subsequently gasified by the blast is preheated, also the ash.
2. The volatile matter in the coal and the water is distilled off.
3. Heat is lost in radiation in the upper part of the producer.
4. There remains a balance of heat in the gas, which gives a definite temperature to the off-going gases.

As there is a given amount of gas at a definite gasification temperature and since the items above are fixed by a given coal, the producer employed and the rate of driving, it follows that the temperature of the gas leaving the producer has a minimum temperature which cannot be lowered by increasing the height of the coal bed above the gasification zone. This temperature can be calculated for each variety of coal.

In the producer operation, when blast consisting of air and H_2O is used, there is an unavoidable surplus of heat which cannot be utilized, except in heating the off-going gases. If there were a smaller volume of hot gases passing through the producer, as, for instance, if the blast contained no nitrogen, then the temperature of the off-going gases would be reduced below the minimum just considered. On the other hand, if blast consisting of air and waste gases were used, the volume of hot gases would be increased and the temperature of the off-going gases would be higher.

Similar conditions exist in metallurgical furnaces and other apparatus used in steel works, as, for instance, the blast furnace, the open-hearth furnace and recuperative furnaces. In the first mentioned, the gas leaves the top at a definite temperature, fixed by the descending materials capacity to take up heat from the ascending gases. Other condition being equal, this temperature cannot be lowered by making the blast furnace, say, twice as high. Only a reduction in the volume of the ascending gases can lower the top temperature.

In the checkers of the open-hearth furnace and in recuperative furnaces, the waste gases can only give up the same amount of heat as the air or gases entering the checkers or recuperators are able to take up. Under such a condition, an increase in size of checkers or recuperators cannot further lower the stack temperature, radiation losses and infiltration of air being equal.

*U. S. Steel Corporation, New York City.

Table 16 represents, as nearly as can be estimated, the heat required for the distillation of two grades of coal. The values are only approximate, but serve, nevertheless, to illustrate the point. The last line gives the heat required per pound of C gasified by blast. The gas created therefrom must give up this heat before passing away from the producer. In Table VII is given the amount of gas created per pound of C at 2000 deg. F. gasification temperature. The heat content of this gas can be calculated and also its temperature after withdrawing the heat required for distillation.

TABLE XVI

Estimate of Heat Required for the Complete Distillation of Medium and High Volatile Coals

	Btu. per Pound	Eastern Coal	Western Coal
Analysis of natural coal (per cent):			
Moisture		3.0	10.0
Ash		7.5	7.5
Fixed Carbon		56.5	47.0
Volatile		33.0	35.5
Total.....		100.0	100.0
C gasified by blast per pound			
of coal		57.5	48.0
C in ash.....		1.0	1.0
Moisture and V.M. driven off			
in distillation zone:			
Moisture		3.0	10.0
V.M.		31.0	33.5
Total (per cent).....		92.5	92.5
Heat required in distillation			
zone per pound of coal:			
Moisture	*1700	51 Btu.	170 Btu.
V.M.	*800	248 Btu.	268 Btu.
To heat C and ash.....	*760	436 Btu.	365 Btu.
Radiation		*170 Btu.	170 Btu.
Total.....		905 Btu.	973 Btu.
Heat required per pound of C			
gasified by blast.....		*1570 Btu.	2020 Btu.

*Approximate.

TABLE XVII

Sensible Heat in Gas per Pound of C Gasified with Blast at 2,000 deg. F. Before Entering Distillation Zone and After Leaving Producer.

	Temperature of gas	Sensible heat above 62° F.
Gas entering distillation zone.....	2000° F.	3675 Btu.
Heat required for the distillation of Eastern Coal per pound of C gasified by blast, see Table XVI.....		1570 Btu.
Gas leaving producer on Eastern Coal...	1280° F.	2195 Btu.
Heat required for distillation of Western Coal per pound of C gasified by blast, see Table XVI.....		2020 Btu.
Gas leaving producer on Western Coal..	1070° F.	1745 Btu.

The result of the calculation is given in Table XVII. The gas temperature for other gasification temperatures is calculated in the same manner. The

results are shown in Fig. 13, and are very instructive. For Western coal, the gas temperature is about 1100 deg. F. and is practically independent of the gasification temperature. For Eastern coal, the temperature varies between 1200 deg. and 1300 deg., except for gasification temperatures above 2000 deg. F. If the gas temperatures in practice are higher than these, this does not indicate that the temperature in the gasification zone is high, but that blowholes exist in the fire bed, allowing air to burn C to CO₂ or pass through and burn the gas. This results in inferior gas and low gasification efficiency, that is, the calorific heat in the gas is transferred into sensible heat. This is detrimental to high combustion efficiency in the open-hearth furnace. For this reason the importance of the measurement of the gas temperature cannot be overestimated. It will be found that in every case with high gas temperature the gas analyses are poor and vice versa.

Blast Temperature and Steam Consumption.

It is generally believed that the blast temperature indicates the amount of moisture going into the producer and can be calculated by assuming the air to be dry and saturated at this temperature. This belief needs to be somewhat modified. When steam is introduced into air, the air is heated and part of the steam is condensed and exists in the blast as fog. The colder the outside air is, the more steam condenses. In most cases, the steam entering the nozzle is also wet, adding still more condensed moisture to the blast. This moisture enters the producer in the blast hood, which usually is only 8 to 10 inches below the hottest part of the fire. The ashes at this point are quite warm and heated by radiation from the fire and it is hardly possible that the fog is trapped in the ashes, taking into consideration also, the high velocity of the blast. Carefully made tests also indicate this.

In several producers, the water seal is so close to the fire zone that some additional moisture vapor is added to the blast from this source. It is well known that the ashes always are moist two or three inches above the seal. A certain blast temperature does not, therefore, give the same gasification condition or gasification temperature in all producers, and this fact must always be kept in mind in comparing results from various producers. On an average, it can be safely assumed that 10 per cent to 20 per cent more moisture enters with the blast than the saturation temperature indicates.

In Table VII the H₂O in the blast at a gasification temperature of 2,000 deg. F. was calculated. In Table XVIII are also given the blast conditions at other gasification temperatures. From this table it can be seen that the blast temperature should not be below 131 deg. F., if 2000 deg. F. temperature of gasification is desired, and in most cases the temperature should be kept from 2 deg. to 4 deg. lower than this, due to the quality of steam used, and a still further decrease is necessary in cold weather. The blast temperature gives a very good indication in operating producers, but one must guard against depending on this for judging the amount of moisture entering the producer, moisture decomposed, or moisture contained in the producer gas. It might be well here to enter a plea for frequent moisture determinations in the gas, which is now seldom done.

TABLE XVIII

Theoretical Amount of H₂O per Pound of Dry Air Corresponding to Various Temperatures of Gasification in the Producer. Also Estimated Temperature of Saturation Under Ordinary Conditions.

	Temperature of Gasification in Deg. F.			
	1600 Deg.	1800 Deg.	2000 Deg.	2200 Deg.
H ₂ O per pound of air in blast (per cent)	.585	.257	.130	.071
Steam required to raise air from 62 deg. F. to saturation temperature (per cent)	.028	.023	.018	.013
Dry H ₂ O in blast.....	.557	.234	.112	.058
Saturation temperature at this moisture content, Deg. F..	176	153	131	110

The approximate consumption of steam for the two coals given in Table XVI can be calculated with consideration of the natural moisture in the air. The actual steam consumption is from 10 per cent to 30 per cent higher, due to steam line losses. In this connection, it might be well to point out the superiority of the turbo-blower over the ordinary steam jet blower as a means of introducing the blast, and the more general adoption of the former cannot be too highly recommended.

The Use of Oxygen in Gas Producers.

This has been proposed by Prof. F. G. Cottrell before the Institute in 1920 and especially by E. A. W. Jeffries in a discussion of Prof. Cottrell's paper.* The effect thereof can readily be calculated in the same manner as shown for blast and H₂O in Tables V, VI and VII. If all air were replaced by pure oxygen, the surplus heat as given in Item B, Table V, is increased by Item 6 in the same table. This will allow and necessitate the addition of more H₂O per pound of C gasified. The percentage of C gasified by H₂O will thereby be increased to 40.2 per cent of the total C, and the resulting gas will contain as calorific heat 89.8 per cent of the heat in C. This compares to 79.4 per cent with air and H₂O at 62 deg. F. With proper consideration of the distillation gases, these percentages indicate that 8 per cent less fuel will give the same calorific heat in the total gas. The gas will be extremely high in calorific value (300 to 350 B.t.u. per cubic foot), and will consist of CO, H and distillation gases, with smaller amounts of CO₂ and H₂O. Due to an increase in combustion efficiency, a possible saving of 15 per cent of the fuel in open-hearth practice may be effected. As about one-half of a ton of oxygen is required per ton of ordinary bituminous coal, the price of oxygen should not exceed about 30 per cent of the cost of coal (cost of additional H₂O not considered) in order to make the process economical for steel works. Such a low price of oxygen is not yet in sight.

The field for the oxygen process, therefore, seems to be exclusively in the production of high calorific gas or so-called "city gas." In this process it is possible to transfer nearly all the heat in the coal into calorific heat in gas.

Influence of Rate of Gasification.

With hand-poked producers, it was considered that 10 to 15 pounds of coal per square foot per hour was

*"The Future of Oxygen Enrichment of Air in Metallurgical Operations", 1920 Year Book of the American Iron and Steel Institute, pages 117 and 139.

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an economical rate of driving in steel works practice. With the advent of the mechanically poked or surface agitated producer, with automatic coal feed, this was raised to 20 to 25 pounds. The most modern mechanical producers, with agitated ash zone and continuous automatic ash removal, have proven that rates as high as 50 pounds are perfectly feasible on most grades of both Eastern and Western coals, still maintaining an extremely high gasification efficiency. In fact, a low rate of driving does not give as high efficiency, due to increased heat radiation from the gasification zone. In the theoretical considerations, radiation losses from this zone were not taken into account. This is proper, as this zone has the shape of a pancake. The radiation loss through the brick-lined wall along the edge of this pancake is practically nil, and the radiation downward is recovered in the blast and transferred back into the zone. The radiation upward is only partly recovered, as far as the gasification zone proper is concerned, but it is only the very top thereof that is affected at gasification rates of 20 to 50 pounds, and this has practically no influence on the gasification conditions. However, at a low rate of gasification, the radiation downward and upward, especially the latter, has a greater influence on the gasification conditions. However, at a low rate of gasification, the radiation downward and upward, especially the latter, has a greater influence on the temperature in this zone, even if it were possible to maintain uniform conditions throughout the fuel bed. In such a case, less than the theoretical amount of moisture can be decomposed. This lowers the efficiency of gasification and makes it necessary to reduce the amount of moisture in the blast, that is, the blast temperature, in order to maintain the proper temperature of gasification.

The practicability of rates of gasification as high as 50 pounds is still doubted by many, but in view of actual results obtained in fully mechanical and automatic producers this does not seem to be justified.

Instruments Required for Controlling and Supervising the Operation of Gas Producers.

1. The most important instrument is a pyrometer, preferably of the recording type, placed in the gas outlet from the producer. It has been pointed out above that good gas and high gas temperature cannot exist simultaneously. A record of the gas temperature from each producer, is, therefore, nearly as indicative of operation as gas analysis, and in some respects more valuable. It will tell the operator practically instantly when a blowhole is formed, and enable him to close it before fusing takes place and clinkers are produced. Twelve, eight or six hour gas samples cannot give such information. If a temperature record is made of the gas from each gas producer, analysis of the gas can practically be eliminated. From a cost standpoint, it is possible that temperature records will not be more expensive than gas analysis from each producer every eight or 12 hours. A few steel works recognize this and have at least partially adopted pyrometers.

2. The gas temperature, however, does not indicate the temperature of the gasification zone. This temperature is closely related to the blast temperature and a thermometer in the blast pipe is, therefore, next to the pyrometer in importance. There are also devices on the market which keep the blast tempera-

ture constant automatically for any rate of driving, and take this important item out of the operator's hands. With these two instruments the conditions of gasification efficiency can be judged.

Other instruments to facilitate the operation are:

3. Steam pressure gauge, showing the steam pressure for the turbo or the jet blower. This indicates the rate of driving.

4. Blast pressure gauge, or U tube, showing the blast pressure. This indicates the condition in the fuel bed.

5. Gas pressure gauge.

6. Measuring device, for measuring the rate of feeding coal. This is usually a simple device when automatic coal feed is used.

There is also an instrument on the market for the continuous recording of B.t.u. per cubic foot of the gas produced.

In addition to these, the operator should have a measuring rod for measuring the depth of the fuel bed, including ash, gasification and distilling zones, and should keep a record thereof.

There are devices on the market that keep the gas pressure constant by regulating the blast. Such a device is useful when a gas producer battery is furnishing gas for heating furnaces, or more than one open-hearth furnace. For open-hearth furnaces equipped with individual groups of producers, gas pressure regulation is not so important.

Preheating of the Blast.

In the comparison between theoretical and actual practice, blast of 62 deg. F. has been assumed in the former case. This is proper, as the sensible heat in the blast in actual practice corresponds to the latest heat given up by part of the steam being condensed to a fog. In the majority of producers, this fog enters the gasification zone also, as pointed out above, and the blast in actual practice, therefore, corresponds to a mixture of air and dry moisture at 62 deg. F.

In the first part of the paper, a few calculations were carried out for blast preheated to 562 deg. F. In Tables V and VI are given the surplus and deficiency of heat when C is gasified by air and steam respectively at 562 deg. F., and in Table VII, the condition when balance is obtained with 562 deg. F. blast. Proportionally more steam is decomposed per pound of C and higher efficiencies of gasification and combustion are obtained. More steam per pound of C gasified must also be used. That preheated blast would increase the efficiency is pointed out by several writers, among others Carl Dichman.*

The Mond Producer system uses blast preheated to a certain degree. From the theoretical point of view, the efficiency of combustion would be increased from about 45 per cent to 49 per cent at a gasification temperature of about 1900 deg. F. This would mean a reduction of fuel consumption of about 9 per cent. Another way to express this is, that preheated blast makes it possible to obtain the same efficiency at a lower temperature of gasification as obtained with natural blast at higher temperature of gasification. However, the heat necessary to produce the additional steam required and to preheat the blast would cor-

*The Basic Open-Hearth Steel Process, by Carl Dichman.

respond to about 7.5 per cent of the fuel. Unless waste heat is used, practically no saving can be expected, and the operation will also be more complicated. In open-hearth practice, there is always sufficient heat in the waste gases, even if waste heat boilers are used, to produce all the moisture vapor required and pre-heat the blast considerably. To solve this problem in a practical way does not seem to be a very difficult one, and a great saving in steam and coal can be realized thereby.

Other Cooling Mediums Than Steam in Gas Producers.

The addition of moisture to blast serves two purposes in the producer:

1. To maintain the temperature of gasification below the fusing point of ash.
2. To increase the gasification efficiency.

The first purpose is the most important, as otherwise, producers could not run except at a very low rate of gasification.

A popular way of expressing the action of steam is that "it breaks up the clinkers." This is not a correct way of expressing the action. Moisture, after it becomes superheated, does not act on coal ash or coal in any different manner than any other gas. Steam prevents clinkers only by cooling the fire. Any other gas could be used for cooling just as well. This was realized some 30 years ago by Siemens, who proposed to use waste gases and many others have since proposed the same or similar method. The soundness of this from a theoretical point of view has not been denied by competent investigators, but the savings that could be obtained have often been grossly exaggerated. That it has not been used to a greater extent is due to practical difficulties. It is necessary that the source from which the gases used for cooling are taken be dependable and that the composition of the gases does not vary to any great extent. The waste gas from the open hearth furnace is not a good source; it varies greatly during each heat and still more during a run. It varies also between reversals, on account of air leakage being different in the two ends of the furnace. With waste heat boilers the conditions are somewhat better, as the gases are practically of constant temperature, but the composition still remains variable. At reversals, there is some gas going directly into the stack, which might cause explosions in the producer blast pipe, and this must be guarded against. Given a constant source of waste gases, the required amount of these must be mixed in constant proportion with air. This, however, does not present a difficult problem.

One of the best sources of waste gases available in steel works is the stack gases from the blast furnace stoves. These gases are very uniform in analysis and temperature when a common stack for each group of stoves is used. These gases consist of CO_2 , N, O_2 and H_2O . In case washed blast furnace gas is used, H_2O is low. The gases can be considered as a mixture of air and true combustion products. The proportion of N to CO_2 in these latter is about 1.8 and this ratio is lower than in any other combustion product. In open hearth waste gases, the ratio is about 2.8. The reason for the low ratio in products from blast furnace gas is that part of the CO_2 in this gas is formed from O in the iron ore and part is derived from the lime-

stone. This low ratio is of great benefit if the gases are to be used in producers, as will be shown presently.

It is possible to calculate the results of adding a certain waste gas with air in the producer. Part of the CO_2 is broken up into CO by oxidizing C, and the resultant gases, consisting of CO_2 , CO and N, are heated to the gasification temperature. These calculations are given in Tables XIX, XX, XXI and XXII for a gasification temperature of 2,000 deg. F.

Table XIX is a chemical balance of materials. The gas obtained contains the same proportion of CO_2 and CO as given in Table III. In Table XX is calculated the deficiency of heat when C is gasified by waste gases of 62 deg. and 562 deg. F. temperature. The efficiency of gasification is calculated in Table XXI. Gas analyses by volume are also given for comparison with those in Table VII. The B.t.u. per cubic foot are low, as compared to gas made by air and H_2O , but the gas does not contain moisture. The gasification efficiency for other temperatures has been calculated. The efficiency for air and moisture blast is about 4 per cent higher; but with air and waste gas blast at 562 per cent F. the efficiency is slightly higher for the latter. The combustion efficiency is calculated in Table XXII. It might be of interest to note here that it requires only 25 per cent to 33 per cent of the waste gases from the blast furnace stoves for operating the producers required to convert all the pig iron into steel in open-hearth furnaces. These figures refer to cleaned, washed blast furnace gas being used in the stoves. Considerably less is required in case raw or dry cleaned gas is used, on account of the moisture contained therein. Such waste gases are sulphur-free and do not add to the total amount of S in the producer gas.

If waste gases, containing 1 part CO_2 and 2.8 parts N, from burning coal are used, the gasification and combustion efficiency are slightly lowered, as the deficiency of heat per pound of C gasified with such gases is higher and less C is therefore gasified by waste gases. It is not necessary to give the calculations here, as they are made in the same way as in Tables 19 to 22. The gasification and combustion efficiency are about 2 per cent to 3 per cent lower than in the case of using waste gases from the combustion of blast furnace gas.

If waste gases contain moisture, this acts in the same way as steam introduced into the blast in ordinary practice, and if the quantity is known, the amount of the waste gases required and other items of interest can be calculated.

In judging the merits of cooling producers with waste gases versus moisture, one must take into account the gas analysis. The former gives a gas high in CO, low in H and H_2O . Moisture gives a gas low in CO, high in H and incidentally in H_2O . In such a comparison, the actual B.t.u. per cubic foot of dry gas by no means form a basis for comparison. One must take into account the combustion efficiencies of the gases, in which the H_2O content must not be left out. It is generally believed, and many practical open-hearth men are thoroughly convinced, that in open-hearth furnaces B.t.u. in the form of CO are more efficient than in the form of H. Actual proof of this is difficult to obtain, but theoretically there is some foundation for such a belief. H_2O dissociates at a somewhat lower temperature than CO_2 . This temperature is reached towards the end of the heat in the

open-hearth furnace, and H therefore requires a higher excess amount of air to burn completely. There are also some practical points. H and H_2O makes a lighter gas than CO and N, and with the former it is more difficult to hold down the flame on the bath. In practice, it is not impossible that the gas made from air and waste gases will show a considerable superiority over ordinary gas.

New Slide Rule Simplifies Design Work

Whenever in any given line of manufacture it is necessary to make a considerable range of sizes of articles, the work of preparing drawings in which such items appear is made irksome by the necessity of referring to rather complicated tables and diagrams by which the standard dimensions of the whole series of articles are shown. In preparing detail and assembly drawings from such diagrams and tables, mistakes are frequently made, either by taking values from the wrong column or line of the table, or by selecting the wrong reference letter in the diagram.

The American Engineering Standards Committee has called attention to a newly developed slide rule for standard parts, which was recently put on the market in Switzerland and was exhibited at the international standardization conference at Zurich. In the use of this novel aid to the draftsman and designer, the danger of making mistakes in transferring standard dimensions to drawing and computations is practically eliminated; and, furthermore, it is used much more quickly and conveniently than the usual tables of standard parts.

The slide rule presents all essential dimensions for the full series of the Swiss standard bolts, nuts and washers, so that by moving the slide to such position that the desired diameter appears through a window or opening in the fixed part of the rule, all the dimensions for the other parts of the bolt of that size appear in the corresponding rectangles on a clear diagram of the bolt which is engraved on the fixed part of the rule. In this way, each dimension appears in exactly the place where it applies. For example, the diameter of the washer appears just where the washer would be dimensioned in any actual drawing incorporating the bolt, nut and washer combination.

In addition to the fundamental dimensions of the bolt itself, the rule provides a convenient means of showing also the diameter of the drill that is to be used for drilling a threaded hole to receive the bolt; the diameter of the cotter pin to be used; the effective cross sectional area of the bolt in square inches; its safe carrying capacity in pounds; and the working stress at that load in pounds per square inch.

The same slide rule carries on the reverse side, a similar presentation of the dimensions of two other standard design components, shaft keys, and gas pipes. This rule illustrates one of the advantages of standardization in favoring manufacturing economy. It is adapted to all cases where standard dimensions have been determined upon for parts, components, or complete machines.

A reprint giving a picture and detailed description of this slide rule is available upon request to the American Engineering Standards Committee, 29 West Thirty-ninth Street, New York City, at whose offices samples of the rule may be seen.—Engineering Standards Bulletin.

A Century of Endeavor

Concealed in the brief announcement that portland cement is now 100 years old, there is a fascinating story; a story of early struggles—of hard-fought contests among men and machines—of spectacular progress once the industry had gained a firm footing.

Picture a small manufacturing town in old England a century ago. Intent upon his unusual endeavor, a mason named Joseph Aspdin is earnestly at work—his goal a superior cementing material. Anxiously he takes a few handfuls of a fine powder and stirs it up with water into a sticky mixture. Impatiently he awaits results.

Harder and harder the mass becomes, growing more and more like stone. At length even the famed building stone from the Isle of Portland—portland stone—was no stronger nor more solid.

"This new material," Aspdin then announced, "shall be known as portland cement."

Next came a long period of development, in which the science of the chemist displaced guesswork in cement making. And with this careful control came a reputation for reliability that brought the material into wide favor abroad.

At length interest was aroused in making this product in the United States. One experimenter utilized his kitchen stove for burning the raw materials into cement-clinker. Another made test burns in a piece of sewer-pipe and ground the resulting clinker in a coffee mill. Crude though the apparatus was and many the disappointments, good portland cement was finally made, and the first American factories established in Pennsylvania and Indiana in 1872.

Then followed a period when imported and domestic portlands competed for favor in this country. Those in charge of important projects had come to rely upon foreign cements; and at first regarded the American product with suspicion. But the domestic manufacturers, by dint of close attention to the quality and reliability of their cement, succeeded in establishing a reputation that eventually won for them the United States market.

During this time of manufacturing development came the wars of the cement-making machines. Against the old time vertical kiln was arrayed the new horizontal rotary kiln—a great steel cylinder with firebrick lining that burns cement-clinker in hours instead of the days needed by the old vertical kiln. And the iron grinding mill—today equipped with huge rotating rolls, tons of tumbling balls, or heavy swinging hammers—similarly disputed the field with the millstones long employed in pulverizing raw materials and cement clinker.

Of course, improved methods won. And fortunately so, for without them present day outputs would be impossible.

In contrast to this country's production of a third of a million barrels in 1890, and eight and one-half million barrels in 1900, the 126 plants in the United States now turn out over 135,000,000 barrels—or 540,000,000 sacks of portland cement in a year. Mixed with sand and stone as used for concrete, it is used but not consumed, and adds to the country's permanent wealth.

Weirton's New By-Product Plant

By C. J. HUNT*

S EVEN minutes past seven on the seventh day of the seventh month, the first coke was pushed from the new ovens at the new by-product coke plant of the Weirton Steel Company, and is significant for two reasons in that it completes the final link in the chain at Weirton, enabling the control of all facilities and processes for the manufacture of the usual raw materials entering into the various highly finished products of the company, ready for delivery to the consumer, and that it inaugurates a new era in the by-product coke industry of interest to the industry at large, being the first battery of ovens designed for high capacity short coking time with 14-in. oven width, to operate in the steel industry for the production of blast furnace coke from high volatile coal exclusively.

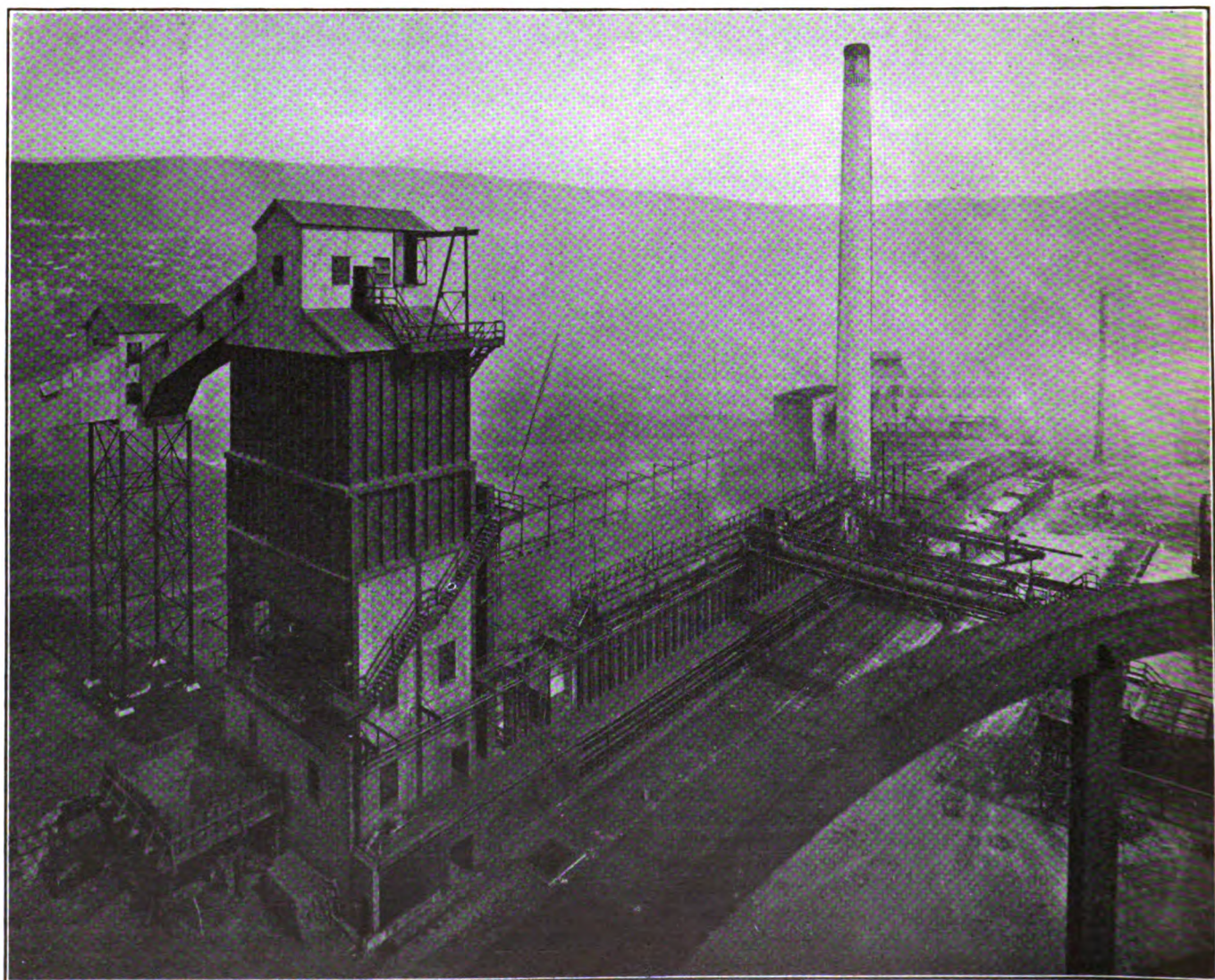
The growth and development of the Weirton Steel Company from its beginning at Clarksburg, West Virginia, in 1905, with the starting of a six mill tin

plate plant, then known as the Phillips Sheet & Tin Plate Company, into the largest independent tin plate manufacturer in the country, operating 50 tin mills and 100 tin stacks and in addition being one of the foremost producers of hot and cold rolled strip steel with two hot strip mills and 40 cold rolling mills and the recent addition of an 8-mill sheet mill plant, complete with galvanizing and finishing facilities, with its own coal mines, iron ore supply, by-product coke plant, blast furnace, open hearth steel plant, blooming mill, bar and billet mills, constitutes one of the most noteworthy achievements within 18 years in the independent steel industry.

A brief review of the order in which these developments occurred was contained in an article by the writer with a description of the steel plant published by the technical press in March and April, 1921.

Including the recently completed coke plant and sheet mill, the company owns and operates eight practically separate plants, the finishing plants comprise

*Chief Engineer of the Weirton Steel Company.



Birdseye view of new by-product plant at Weirton, showing coal handling tower at left and Koppers ovens in the main foreground.

12 tin mills at Clarksburg, 12 tin mills at Steubenville and 26 tin mills at Weirton, having a capacity of 225,000 tons or equivalent to 4,500,000 base boxes of tin plate annually, the hot and cold rolled strip steel plant at Weirton, with a capacity of 200,000 tons of hot rolled and 60,000 tons of cold rolled strip steel annually, the sheet mill plant at Weirton with an annual capacity of 60,000 tons of black and galvanized sheets.

Almost from the first the company foresaw the time when they would require their own source of raw material supply, therefore in 1909 when the site was selected for the erection of a new tin plate plant, consideration was given to a location which would provide space for the erection of such facilities and for additional finishing mills; the present town of Weirton with a population of about 12,000 persons and the modern self-contained plants there is the result of that foresight and vision.

Early in 1917, the company's engineers developed the plans for the present and ultimate steel making units, including blast furnaces, steel plant, rolling mills and by-product coke plant, an analysis of the consumption of the finishing mills indicated there would eventually be required steel making capacity for 75,000 to 80,000 tons of ingots per month and the entire layout was designed to permit of these eventual requirements. The blast furnace department was laid out for the eventual construction of three furnaces, the by-product coke plant for three batteries of ovens and the open hearth plant for 14 100-ton furnaces, with rolling mills to take care of the ultimate tonnage.

The present 600-ton blast furnace was the first of these units to be constructed and was blown in July 21, 1919, being built to operate temporarily as a merchant furnace until the steel plant was constructed, its building being hastened in advance of the steel plant to assist the country in the war emergency due to the shortage of pig iron needed for war materials and munitions, a sufficient supply of beehive coke to meet the requirements of the furnace was obtained by the purchase of an interest in the mines and ovens of the Redstone Coal and Coke Company, near Brownsville, Pa., in the Connellsville region.

In June, 1919, ground was broken for the present steel plant consisting of seven 100-ton stationary open hearth furnaces, 40-in. blooming mill, 21-in. continuous roughing mill and 18-in. continuous bar and billet mills, this plant going into operation in November, 1920.

During this construction ladles and cars were purchased and changes were made at the blast furnace to deliver hot metal to them for movement to the adjacent mixer building housing a 1300-ton mixer, hot metal being charged direct to the open hearth furnaces from the mixer as required.

The need of by-product coke ovens located adjacent to the blast furnace and steel plant was felt even before the steel plant went into operation, not only on account of the high cost and waste of beehive method of making coke but also to the difficulties in maintaining schedules of movement from the mine to the furnace due to uncertainties of transportation, strikes and car shortage, it being necessary to purchase 240 coke cars to be assured of cars to move the coke as required.

The plant had been laid out in the beginning for construction on a site located on the Ohio River bank

paralleling the tin mill plant with arrangements for receiving coal by river and unloading it from barges and delivering it to the breakers at the coke plant with storage space provided for 280,000 tons as insurance against low or frozen river and other contingencies. River equipment and unloading docks, also loading facilities up river to permit of transporting coal by water are to be installed in the near future. This location permits a system of gas lines for distribution of the surplus gas from the coke plant to the other departments of the plant where its use will effect the greatest economies, and with the completion of river transportation will make possible the delivery of coke to the blast furnace entirely within the company's control and at the lowest possible cost.

All of the scrap produced by the finishing mills is used at the open hearth plant, the most of which is light sheet scrap from the sheet and tin mills and crops from the hot and cold strip mills, this material being hard to handle to the furnaces and slow to melt down, it is essential for fast production to receive a maximum amount of hot metal from the blast furnace and for the further reason that the amount of hot metal and scrap produced is not sufficient to make the quantity of steel required, it being necessary to purchase the remainder in the form of scrap from outside sources.

Therefore in the consideration of a by-product coke plant, the first requisite was for a quality of coke which would permit of maximum production from the blast furnace from as large a percentage as possible of the company's ores, secondly as the company purchased the entire interest in the mine and property of the Redstone Coal & Coke Company in November, 1922, and also owns 1,000 acres of coal on the Monongahela River at Brownsville, Pa., that this coke be made from the maximum percentage of this high volatile coal, as the addition of low volatile coal would materially increase the cost of the coke on account of its higher cost and long freight haul from the Kentucky and West Virginia fields, and also its production and transportation not being under the company's control, the elimination of the necessity for it was highly desirable.

The problem then was to determine whether a coke possessing the following qualities and characteristics generally accepted by blast furnace and coke oven operators as necessary for good blast furnace performance, could be made from 100 per cent high volatile coal.

Good combustibility so it would burn equally at the tuyeres of the blast furnace, maintaining the zone of combustion low down in the bosh of the furnace where it is needed.

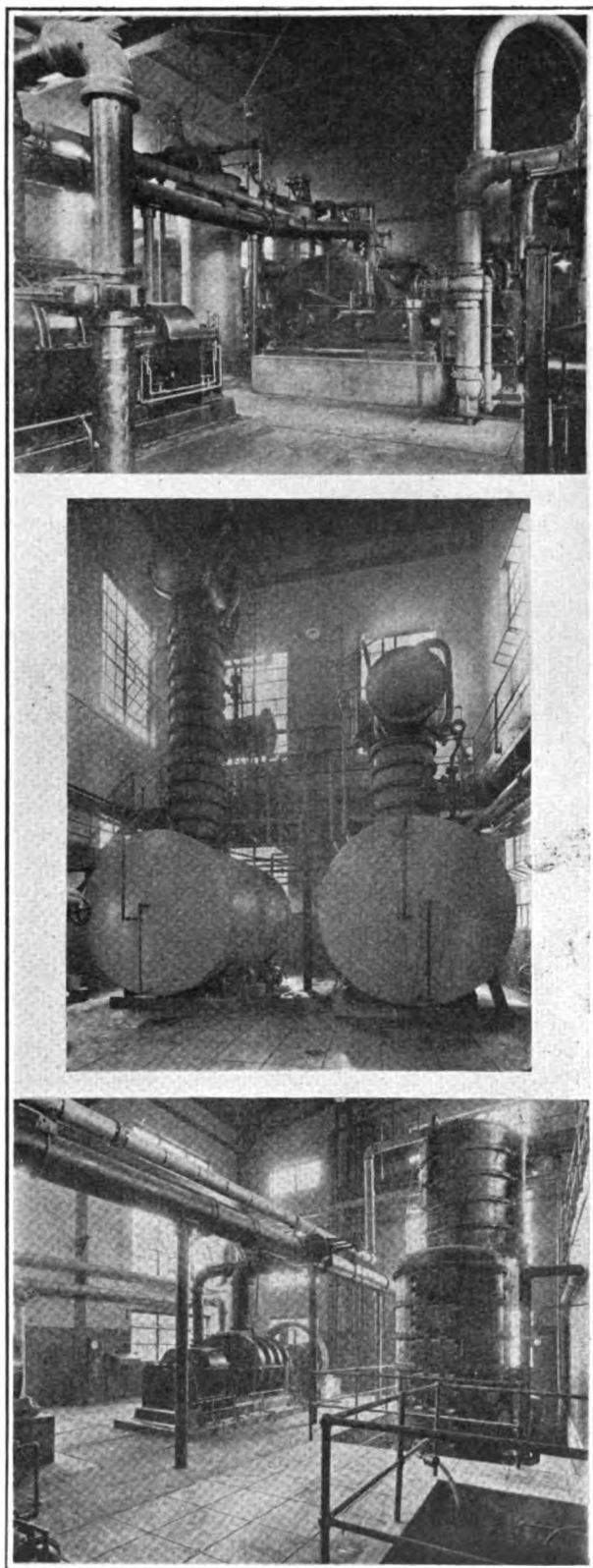
Strength to prevent crushing in the furnace due to heavy weight of the burden.

Uniformity of cell structure.

Absence of cross fracture causing it to break in small pieces when being handled from coke plant into furnace. Of blocky instead of finery structure.

Uniformity of size.

Various coking coals and mixtures of coals require different treatment during the coking process, such as length of coking time and degree of heat under which the coking is completed to produce coke best suited for blast furnace purpose.



Three views taken inside the benzol plant.

The following is a fair average analysis of the coal to be coked:

Volatile Matter	33.25%
Fixed Carbon	57.97
Ash	8.50
Sulphur	1.09
Moisture	2.5 to 3.5

While a first quality coking coal mixture will make good coke independent of oven width and temperatures, this is not true of straight high volatile coal especially with coal containing over 33 per cent volatile matter, for the reason that such coals contain an excess of bituminous matter which during the process of distillation in the oven, has a tendency to condense in the center of the charge and to form a spongy coke of low quality.

The customary remedy for eliminating sponge in the ordinary type of oven and one that is nearly always effective, is to mix with the high volatile coal, a sufficient quantity of low volatile coal to effect the absorption of the excess bituminous material and to eliminate the condition of sponge formation. Different coals require considerable variant percentages of low volatile coal to completely eliminate the sponge.

Coals containing over 30 per cent volatile matter are also apt to have a fingery tendency in coking, that is the coke forms with a greater number of seams perpendicular to the oven walls which on account of the small cross section break up into small short pieces during the necessary handling. This becomes pronounced if the coal is of high oxygen content and is likewise encountered in coals which have remained in stock piles for a considerable length of time.

It has been demonstrated to the satisfaction of the majority of coke oven and blast furnace operators, that especially from high volatile coal better coke can be made in narrower ovens and by careful study of the results obtained and tests made with high volatile coal in the five Koppers experimental ovens of the Becker type, 14 in. wide, at the plant of the Chicago By-Product Coke Company, it was found that the percentage of such low quality coke can be reduced and in fact practically eliminated by coking to the center of the charge quickly, so as to avoid excessive condensation and spongy formation toward the center; this can be accomplished in the narrower oven to relatively lower coking temperature as the narrow fused coking zones are driven to the center of the oven from both walls more quickly in the narrow than in wide ovens, due to the shorter distance the heat must penetrate through the heat resisting coked portion to reach the center.

Also when coking high volatile coals or coals of a high oxygen content, by coking at temperatures somewhat lower than used in ordinary practice, the fingery tendency may in many cases be entirely eliminated, as over-coking and high temperatures tend to produce fingery or small size coke, and by careful heat treatment, well regulated during the coking process, especially in the case of the narrower ovens, firm blocky coke may be made from coal usually regarded as having a fingery tendency.

The heat applied to the coking mass from the oven wall must be uniform from end to end of the oven and also from top to bottom of the oven, except for the usual thin layer on top of the coking mass to protect the space in the upper part of the oven through which the gases pass from the oven from high temperatures destructive to by-product recovery and the coking should reach the center of the oven over the total area of the oven at the same time, otherwise the portion which has been completely coked will become over-coked in order to complete the portion that was lagging behind. With the old style wide oven, it is necessary to apply the heat longer and at higher temperatures to drive the heat to the center of the coal mass.

This produces coke of unequal structure from wall to center, due to over-coking at the wall end and is apt to cause cross fracture, while with the narrower oven with shorter coking time, the heat will penetrate to the center of the oven with equal or even lower temperatures in a shorter time and make a more uniform strong blocky coke.

After a thorough investigation of various types and designs of ovens, the new development by the Koppers Company in the coke oven design as embodied in the Becker type of narrow width, was chosen as fulfilling various requirements essential to the conversion of high volatile coal into blast furnace coke. This type of oven was fully described in a paper by Joseph Becker, read before the Eastren States Blast Furnace and Coke Oven Association and since reprinted in whole or in part in the various trade journals.

In the old style Koppers ovens operating on longer coking time, the quantity of gas per flue becomes correspondingly less and the combustion is quicker and the flame shorter so that the bottom of the oven is completely coked in advance of the top and in order to complete the coking of the top portion, longer application of heat at the bottom increases the temperatures in the oven walls, causing over-coking of the mass in the bottom of the oven.

In the new type of oven, which is of the vertical rectangular flue design, one side of the oven is heated in its entirety. The products of combustion joining in the horizontal flues pass over the top of the oven, through cross-over flues, one pair of which is located on the coke side and the other pair on the pusher side—the products of combustion then enter the horizontal flues of the adjacent heating wall and pass downward throughout the entire wall into the regenerators.

The flow of gases has been worked out so that there is a minimum of leakage between individual flues since adjacent flues are all working under the same flow and pressure condition, there being no counterflow in any adjacent heating flues. This theory has also been carried out in the arrangement and design of the regenerators, which reverse longitudinally with the battery instead of crossways as in the older type.

Due to the design of these flues and the faster heat absorption, the height of the flame in the flues has been increased and extends far up toward the top of the oven with the result that the heating of the cold charge is uniform over the entire area in contact with the oven wall, so that the coking reaches the center of the oven over the total area at virtually the same time.

The ovens were built with combination regenerators to permit the use of blast furnace or producer gas at any time, so that all of the coke oven gas can be utilized as fuel throughout the plants, and in case producer or blast furnace gas is used, the arrangement of regenerators and flow of gas is such that there does not exist at any time counterflow between incoming fuel gas and outgoing products of combustion in adjacent regenerator chambers. Fuel gas and outgoing products of combustion are separated by a regenerator containing ingoing air and should a slight leakage occur in the waste gas regenerator chamber, it can only result in the loss of air and it would be impossible to waste producer or blast furnace gas. These features minimize the dangers of leakage from one part of the oven to the other as the battery gets old, with

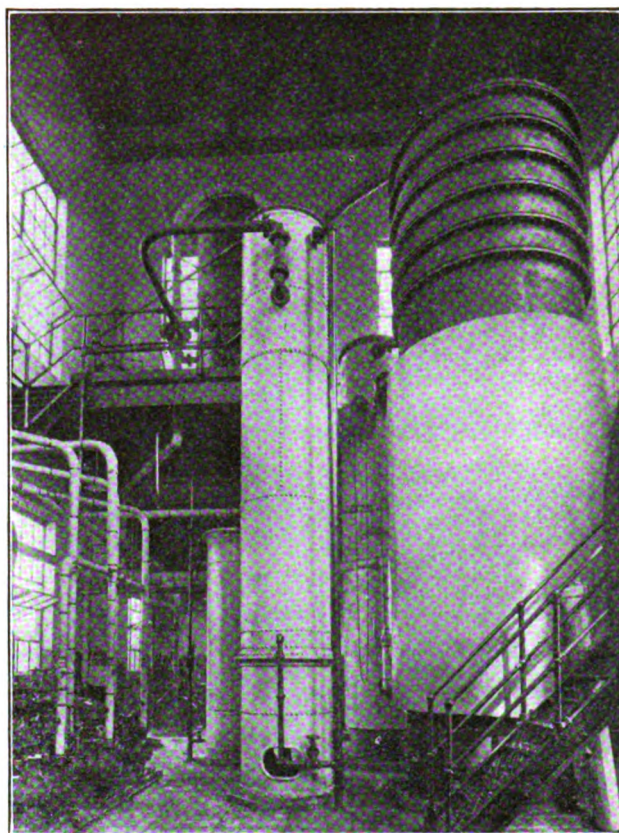
lessened liability of damage by local overheating of the brickwork on account of leaks through cracks or joints, due to the relatively low differential pressures existing in any part of the battery.

The arrangement of flues and regenerators is such that it has been found possible to maintain lower uniform stack temperature indicating less waste of heat to the stack and lower fuel consumption for heating the ovens due to more efficient heat distribution and transmission to the coal.

The following comparison at Chicago indicates the above advantage of the new design of oven:

Width of Oven	Coking Time	Flue Temp.	Stack Temp.	Flue Gas Pressure	Stack Draft	Flue Differential
14 in.	14 hrs.	2300° F	500	150 MM	23 MM	6 MM
16 in.	16 hrs.	2550	575	90 MM	14 MM	9 MM

From which it will be observed that the new type of oven operates at an equivalent coking speed with



Interior of benzol building showing the wash oil still with the final heaters in the rear, the light oil cooler and separator and the vapor to oil heat exchanger on the platform above. The wash oil circulating pumps are in the lean to the rear and the charging and loading pumps at the left.

less flue temperatures, also lower stack temperature with a more nearly balanced condition indicated by the lower flue differential pressure.

By tests made on the experimental ovens at Chicago, it was demonstrated that about 200 deg. less temperature was required in this type of oven for the same oven width as compared with the older type.

With the same flue temperature, the new type 14 in. oven would coke in 11 hours as compared with 16 hours coking time of the old type 16-in. oven.

The coke from the new ovens is more uniform in temperature when pushed, also both in size and structure and from all parts of the oven as it is unnecessary to over-coke one portion of the oven in order to properly coke another.

Porosity of coke from 16-in. oven—52 per cent; comparative porosity of coke in 14-in. oven—55 per cent.

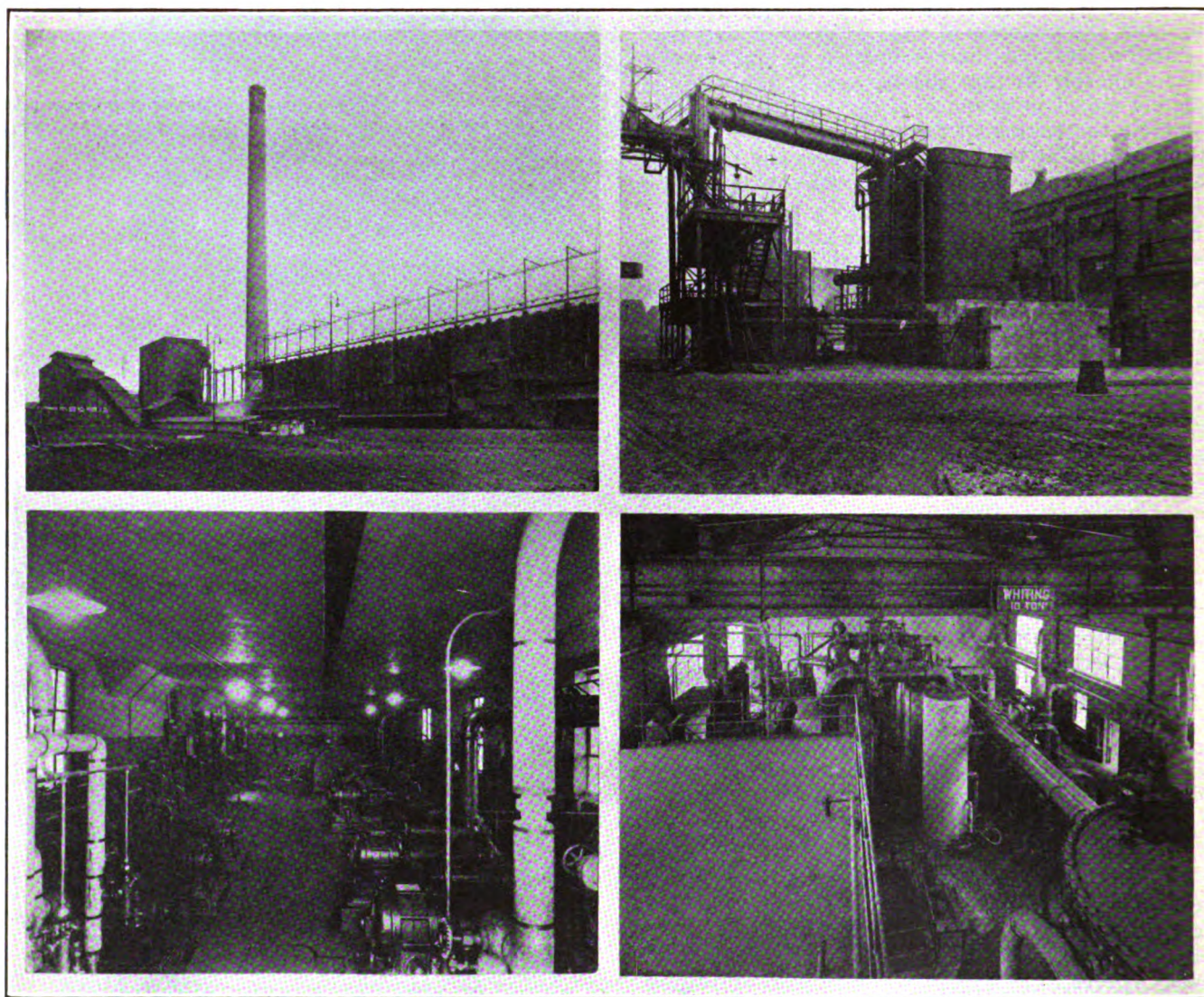
The shatter test shows 10 per cent better on coke from 14-in. oven and with better combustibility.

That coke can be made from high volatile coal with lower temperatures in the heating walls in the new type of oven as compared with the old type without sacrificing speed.

These various points were considered sufficient to justify the building of a plant to operate exclusively

with high volatile coal, although provision has been made in the layout for the installation of pulverizers and for mixing coal should it be deemed necessary or feasible in the future to do so. In this decision, the Weirton Steel Company was the pioneer in the adoption of the new type narrow oven, as the plant would go into operation a year before any other ovens contracted for or contemplated would be finished.

The demand of the blast furnace was for not less than 600 net tons of furnace coke per day, to meet this demand it was decided to install one battery of 37 ovens, each oven having a capacity of 544 cu. ft. or 13.6 net tons based on coal at 50 lb. per cu. ft., thus establishing a new record for the minimum of ovens required for a like production of coke per day and consequently for minimum investment required per ton of coke produced.



Coke side of battery showing quenching car and its electric locomotive ready to receive coke from the oven. The coke wharf is shown in the middle foreground with the quenching station and the coke screening and loading station at the left.

Interior view of the pump room under the primary coolers—the by-product department pumps are in the foreground, the water service pumps beyond at the right and the air compressors at the rear.

The primary coolers in the middle foreground rest on a reinforced concrete structure forming a room which houses all by-product department pumps, water service pumps and air compressors. The gas collecting main from the ovens, the pitch trap and the hot drain tank which is located above ground level are shown at the left, the by-product building at the right. The gas holder, tar and ammonia liquor tanks are shown beyond.

Interior of the by-product building showing two lines of apparatus, one in operation, one as a spare. The exhausters are at the right, the sulphate drain table and centrifugal dryers are located on a platform at the left.

The builder guaranteed this production of 600 tons of furnace coke per day over a $1\frac{1}{4}$ in. revolving grizzly screen, coke passing through the grizzly to be re-screened on a $1\frac{1}{4}$ in. shaking screen and all coke passing over this screen to return to the furnace coke.

The Ovens.

The ovens are 41 ft. 0 in. long, face to face of doors 12 ft. 8 in. high, $13\frac{1}{4}$ in. wide at the pusher side and $14\frac{1}{4}$ in. wide at the coke side, an average of 14 in. width. The ovens are spaced 3 ft. $6\frac{1}{4}$ in. center to center and are the Koppers patented cross regenerative combination oven with two regenerators per ovens, so that they can be operated in the future with either producer gas or coke oven gas, the heating chambers are rectangular flue construction with 31 vertical flues, four cross-over flues connect the horizontal flues on either side of the oven chamber.

Sil-O-Cel insulating material is used to insulate the ends of the regenerators, the horizontal flues and the cross flues, cast iron face plates are provided between the vertical buckstays and the brickwork between the ovens, these are sectional of the same height as the jamb brick and extend in to form the jamb for the doors; the lintels also being faced with cast iron lintel plates. Sil-O-Cel insulation is provided in spaces between the brickwork and the jamb plates and also as packing in the oven doors, assuring comparatively cool benches.

The pusher side bench is 7 ft. 4 in. wide and the coke side bench 7 ft. 10 in. wide with smooth finished reinforced concrete floors; also extending across at each end of the battery to form connecting walks.

A brick enclosed room at bench level at the east end of the battery, back of the pinion walls contains the reversing mechanism and battery instruments while at the opposite end of the battery underneath the coal bin at bench level are two rooms also brick enclosed, one containing the wet pan for mixing luting clay with storage and handling facilities for same, the other a service and sanitary station for battery coal and coke handling men.

The fuel gas for heating the ovens is delivered from the 10000 cu. ft. fuel gas holder through a 16-in. main by two branches with a Venturi meter in each branch to a 12 in. main on each side of the battery, from which it is introduced alternately to each side of the ovens by reversing cocks and connections with regulating cocks to the gun brick connecting to the ports in each heating flue. The gas gun castings are provided with decarbonizing caps connected with the reversing mechanism so that they open on reversal of the gas to the opposite side, admitting a small quantity of air through the gun brick and nozzles burning out any carbon deposited there.

The air for combustion enters the regenerators for each oven through cast iron reversing valves four for each oven, one on each end of the two regenerator chambers. These valves also serve to convey the waste gases to the waste heat flues a cast iron disc valve operating between air and flue openings, a butterfly damper in the flue connection to each valve, hand adjustable, provides individual regulation of the draft conditions from the regenerators while finger bars over the air inlet openings control the amount of air admitted affording complete control of air and draft to compensate for relative distance of oven to stack and other variable conditions.

The waste heat flues from each side of the battery are connected to a common reinforced concrete stack 8 ft. 0 in. diameter, 200 ft. high with perforated radial brick lining, a regulating damper is provided in each waste heat flue and a stack damper in the flue leading to the stack, thus providing means for controlling the draft on each side of the battery and for the battery as a whole, and as is common in the Koppers ovens with means for regulating the admission of gas and air to each vertical heating flue by changeable gas nozzle brick and by adjustable sliding brick over each flue regulating the down draft in each flue, every facility is provided to control the heating so as to maintain uniform temperature from end to end of the ovens and in all ovens from end to end of the battery, which has proven of particular advantage in this plant for properly coking high volatile coal.

The air and draft valves and gas reversing cocks are all operated by a single reversing unit, motor and timed to reverse every 20 minutes by an electrical timing device energized by a clock.

The gas from the oven enters the collecting main through ascension pipes provided with cast steel butterfly valves, the collecting main is 60 in. diameter, gas leaves the ovens at a temperature of approximately 1000 deg. F. and is sprayed with tar and ammonia liquor by sprays located about every four feet along the main, so that the gas enters the suction main at less than 210 deg. F. The collecting main slopes from both ends toward the 36-in. suction main connection at the center of the battery, the heavy tars are condensed out of the gas in the collecting main and washed along by the flushing liquor to the suction main which is so arranged that the tar and liquor flows from the collecting main through pitch traps and back through the suction main to the hot drain tank, while the gas passes through a by-pass with butterfly valve for regulating the gas pressure in the collecting main, controlled by a Koppers automatic governor operated by oil pressure.

Coal and Coke Handling.

Fig. 1, see April issue, shows the general plan of the plant and the provisions for extensions including coal handling facilities from river barges. Coal is received at present by rail and can go direct to the ovens or be sent to storage by discharging from the bottom of the cars into an unloading pit and thrown back onto the storage pile by a fixed radius whirly crane operating on a semi-circular track. This crane is equipped with a 5 cu. yd. bucket and boom 100 ft. long, and is also utilized for reclaiming from storage into cars for delivery to the ovens, this arrangement being adequate until such time as additional batteries are added, when more extensive storage and reclaiming facilities are contemplated.

Coal going to the ovens is delivered to the unloading building at yard level and from the bottom of the cars into two track hoppers. Duplex reciprocating feeders deliver the coal onto a 36-in. belt 20 ft. 0 in. below yard level, which conveys up an 18 deg. slope to the junction house at yard level and onto a 36 in. belt at right angles, also at a slope of 18 deg. to the top of the breaker building 35 ft. 0 in. above the level of the yard.

(To be Continued)

CURRENT TECHNICAL DIGEST

America's Industrial Armada Leaves for Spain

America's industrial "Armada" to Spain, a 34-car train of steel mill plant electrical equipment for the Cia Siderurgica del Mediterraneo (Metallurgical Company of the Mediterranean) at Sagunto, Spain, left the East Pittsburgh works of the Westinghouse Electric & Manufacturing Company, Monday, January 28. The total value of the shipment is more than \$500,000 and is part of a development, costing many millions, of which that represented by purchases in America approximates \$2,000,000.

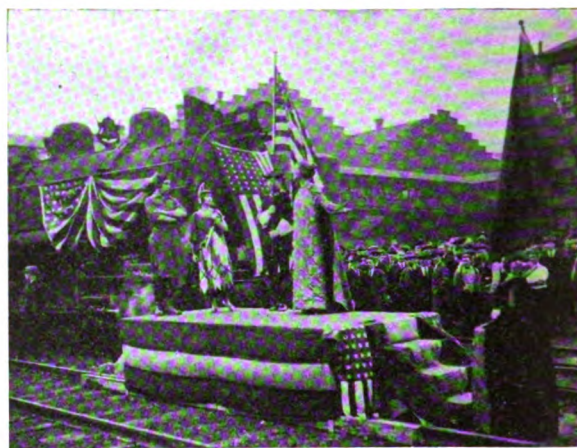
The shipment represents a great forward stride in Spain's industrial progress as the electrical equipment contained in the shipment, when installed, will drive the first complete electrically equipped modern steel rolling mill plant in that country.

Just before the departure of the train from East Pittsburgh an interesting pageant was staged by students of the Dramatic School, Carnegie Institute of Technology. A man, representing industry, and three girls, representing the United States, Spain and Queen Electricity, took part in the pageant depicting the United States congratulating Spain on her industrial progress. At the conclusion of the ceremony, Queen Electricity christened the shipment the "American Industrial Armada to Spain." Then the train slowly pulled out of the yards on the first leg of its long journey.

The Sagunto plant, which will be among the most modern in the world, was designed and constructed under the drawings, specifications and supervision of Frank C. Roberts & Company, prominent consulting engineers of Philadelphia. The plans call for the complete works, including coal dock, by-product coke

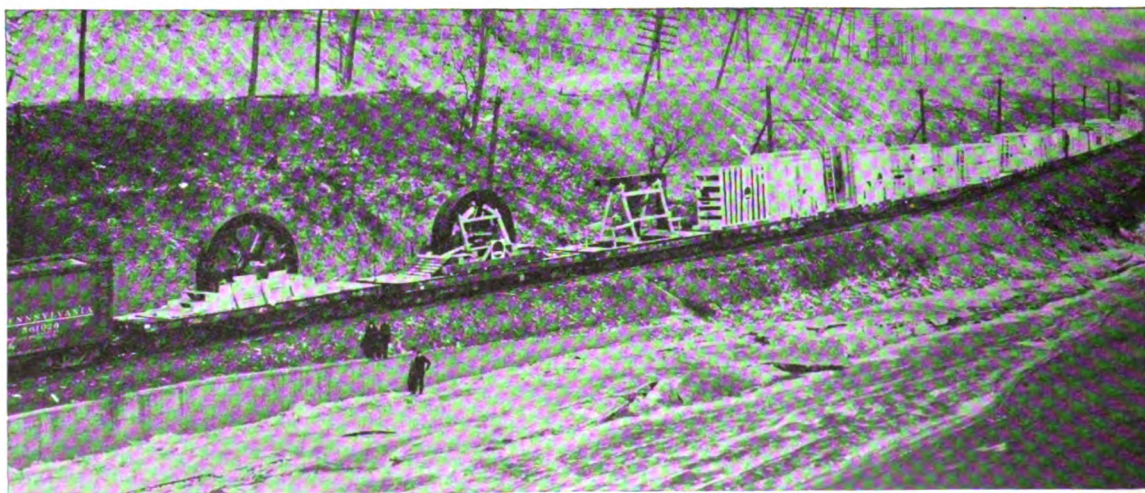
ovens, blast furnaces, open hearth steel furnaces and rolling mills for an ultimate capacity of 1,200 tons per day of finished product. Practically all of the plant is electrified and controlled with Westinghouse equipment.

Sagunto is the ancient town of Saguntum, captured by Hannibal 219 B.C., and is ideally situated for the new plant, according to Mr. Roberts. The iron ore



Pageant staged by Carnegie Tech dramatic students.

lies in deposits that were worked by the Carthaginians and are located in Sierra Manera mountains, about 130 miles from Sagunto. The ore is transported to Sagunto over the company's own railroad. From this point Spain exports vast quantities of ore to the United States and various countries of Europe. The company operates its own fleet of 50 ocean steamers.



Train load of electrical equipment leaving East Pittsburgh for Spain.

The vision of a modern American iron and steel works against the background of the ancient town of Saguntum with all its traditions and history arouses a realization of the progress of the human race.

Mr. Roberts was also the American agent in the transaction and much credit is due to his expert counsel and design that America landed this business in the face of keen European competition.

Sota and Aznar, the holding company of the Cia Siderurgica del Mediterraneo, have been assured of the hearty support of the government and industrial organizations of Spain in developing the new plant.

Practically all the machinery and equipment of the mill is of American design and manufacture and the actual operation will be in conjunction with experienced American steel men.

That Spain regards American methods of design and operation very highly is attested to by the complete American installation of this important plant in the leading industry of the world.

The shipment included a 5,000-hp. motor, which will be installed in a 48-inch blooming mill, which is larger than any mill ever used in the United States; a 3,750-hp. motor for a 28-inch structural mill; a three-unit motor generator set, consisting of one 3,500-kw., and one 3,000-kw. generator with a 180,000-lb. fly-wheel, all driven by a 5,000-hp. induction motor; a four-unit exciter set, blower and air washer equipment for forced ventilation, switchboard and automatic control equipment.

This comprised one unit of the shipment. There was also included a 3,000-hp. motor for driving a 36-inch three-high plate mill, and its gear unit, in addition to the driving motors. The shipment includes 85 auxiliary mill motors with automatic control equipment for use in the various mills. There are also included three rotary converters with accompanying switchboard and three transformers, each with a rating of 1,100 kva.

The shipment after leaving East Pittsburgh proceeded immediately to Port Richmond, Philadelphia, where it will be loaded on ships for the journey by water.

Prior to actual ceremony of christening the train, a mass meeting was held in the Westinghouse Lunch Club, where employes of the company gathered to hear addresses given by President E. M. Herr and Works Manager R. L. Wilson. Both speakers impressed their audience with the importance of the shipment as a messenger of electrified industry to Spain and congratulated all the workers for their co-operation in producing the equipment.

The Mercury Boiler

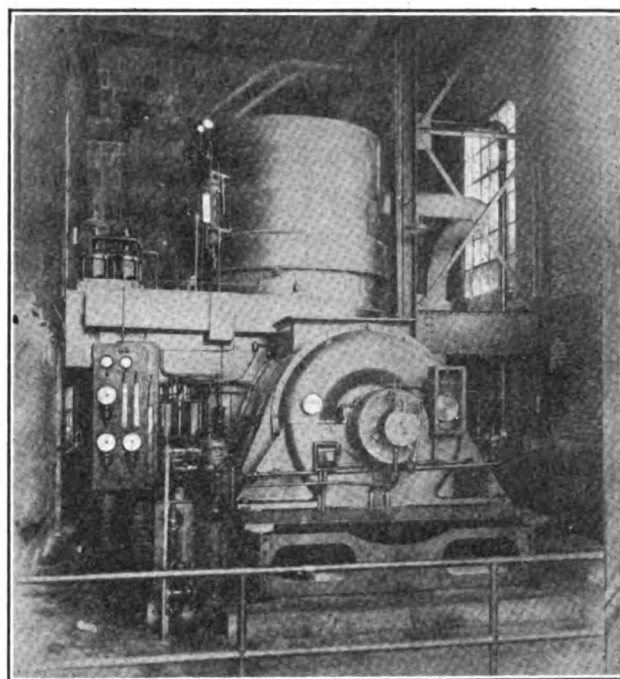
The first mercury engine in the world, for the production of power in commercial quantity, is now in operation in the plant of the Hartford Electric Light Company whose officials predict a saving of from 40 to 50 per cent of fuel by its use. The invention is essentially a turbine engine run by mercury vapor. The whole electrical industry is interested in observations being made of its operation.

Incentive for a careful investigation of the properties of mercury vapor for power generation is given by the high cost of coal and its transportation, making it necessary to minimize fuel consumption. The mercury boiler was started up successfully early in Sep-

tember and has since been in regular operation, carrying a part of the commercial load of the local lighting system. Officers of the local lighting company say that it has carried approximately 3,500 kw. of the Hartford load.

While the present installation is not of sufficient size to have any effect on total cost of power produced by the company at the present time, it is large enough to provide a working basis to figure the results that may be obtained eventually from larger sizes. The manufacture of these boilers is so intricate that it will be several years, probably, before the larger boilers can be in operation.

It is expected that the mercury boilers will be a very material improvement over the most modern stations, even those contemplating using 1,000 and 1,200 pounds of steam pressure. The new process will require only about one-quarter of the fuel that is used with the best reciprocating engines.



First mercury boiler operated at Hartford, Conn.

The mercury vapor exhausted by the mercury turbine is sent to a condenser where it is cooled by water, just as in any ordinary power system. But the mercury vapor is so hot that the "cooling water" is turned into high-pressure steam. This steam is not wasted, but is sent to a steam turbine from which additional power is obtained. This still further increases the efficiency of the system.

It is the object in making such installations in the future to replace the steam boilers in the large modern plants by a mercury boiler which will give nearly double the output in the same place. Consequently, it will not be necessary for a general redesign of a station to obtain the benefit of better economy.

The process was invented and designed by Dr. W. L. R. Emmet of the General Electric Company. As the characteristics of mercury vapor had never been thoroughly studied by other scientists, it was necessary for him to go into this general subject in great detail. It was found that no form of packing of the joints would resist the mercury vapor and a system of

arc and acetylene welded joints was therefore developed.

In this connection it is of interest to recall that the Hartford Electric Light Company installed the first commercial sized steam turbine in this country.

The possible efficiency of the mercury vapor process for the generation of electrical power is equivalent to that of internal combustion engines, its inventor, W. L. R. Emmet, consulting engineer of the General Electric Company, said in a statement requested by Science Service. Since the new process involves only simple rotation and is applicable to any kind of fuel, Mr. Emmet expects it to be "simple and practicable for application to a variety of purposes" just as soon as the commercial installation at Hartford is given a severe service trial and mechanical difficulties are fully overcome.

The mercury boiler and turbine is not yet ready for general commercial application, Mr. Emmet said, as the development of such a process involves a very large amount of experimentation and accumulation of experience, both in methods of construction and the proportioning of boilers and condensers.

In discussing its efficiency, Mr. Emmet said:

"The possible rate of gain which may be accomplished by proposed mercury vapor process, as compared with steam plants, is naturally dependent upon the conditions and efficiency of the plant with which comparison is made. To give an idea of the possibilities it may be said that, if we compare with a steam turbine generating plant, using 200 lbs. steam pressure, with the highest standards of efficiency in turbines and auxiliaries, the mercury steam combination with 35 lbs. gauge pressure in mercury vapor should give about 52 per cent more output in electricity per pound of fuel. And, if in such a plant the boiler room is re-equipped with furnaces and mercury apparatus arranged to burn 18 per cent more fuel, the station capacity with the same steam turbines, condensers, auxiliaries, water circulation, etc., would be increased about 80 per cent. As compared with higher steam pressures, such as are now being developed, the percentage of gain would naturally be less, but still very important."

The mercury is re-used many times, unlike the water used in steam boilers. Mr. Emmet expects that less than five pounds of mercury per kilowatt of capacity will be required when the process is operated on a large scale.—General Electric Bulletin.

Following are some of the more important articles and market reviews which have appeared in Iron Trade Review, February 7 to date:

FEBRUARY 7

General tendency of production is upward, although the Steel Corporation this week is operating at 91.5 per cent of steel capacity which is slightly lower than the peak point of the preceding week. The feature of the week's market is the fact that the National Tube Company closed for a round lot of basic iron for Lorain, Ohio, estimated at 40,000 to 60,000 tons. Sales of pig iron for the second quarter have been active. Iron Trade Review's composite of 14 iron and steel products still is rising, registering \$43.49 this week against \$43.39 the week preceding. Pig iron production in January increased for the first time in seven

months. The total output was 3,017,444 tons compared with 2,912,519 tons in December. The daily average increased from 93,952 to 97,337 tons or a 3.6 per cent gain. Eighteen blast furnaces were put in operation during the month, and only one was blown out.

The British iron and steel trade is recovering slightly from the effects of the railroad strike. Loss of production of Welsh tin plate, due to the strike is estimated at 340,000 base boxes. Continental makers continue to make low price offers in the export field. The Germans are building new steel works at Kiel outside of the zone under French control.

Luther Becker, chief of the iron and steel division, Department of Commerce, contributes to this issue a comprehensive article on the iron and steel requirements of Japan, with the conclusion that Japan has become the best export market for American iron and steel.

H. R. Simonds, Boston representative of Iron Trade Review, describes the use of alloy and special steels in the construction of bank vaults. The transactions of the American Society for Steel Treating at its winter sectional meeting at Rochester, New York, are presented in this issue.

The complete record of iron ore shipments for the Lake Superior districts for 1923 shows a total of 60,780,003 tons, an increase of 16,789,907 tons over 1922. The output per active mine was larger than in the record year of 1916 when 66,658,466 tons of ore was forwarded. Fifteen mines of the Oliver Iron Mining Company, steel corporation unit, shipped 24,580,148 tons in 1923 or 40 per cent of all the ore forwarded.

FEBRUARY 14

Steady progress is being made in second quarter business in the pig iron market. Bookings of basic iron in the New York and Philadelphia districts mark this as one of the heaviest buying periods the eastern trade has known in many months. An eastern subsidiary steel corporation closed for 30,000 tons of basic at a price report under \$22 delivered. Prices show considerable firmness. Iron Trade Review's composite of 14 products has advanced to \$43.50.

The steel market also shows increased activity. Recovery of steel ingot production in January after four months of losses is at a more rapid rate than in the pig iron. The output totaled 3,599,938 tons, an increase of 756,174 tons or 17.2 per cent over December. The Steel Corporation reports an increase of 353,190 tons in unfilled orders for January. Construction and railroad requirements are bringing out a heavy demand for steel.

One of the largest enterprises ever undertaken in the iron and steel jobbing field is revealed in the projected merger of more than 30 eastern warehouses with a capitalization of at least \$40,000,000.

French and British producers are competing with American mills for business along the Atlantic coast, and offer prices \$5 to \$10 below those quoted by home mills.

Iron Trade Review's London correspondent reports that deliveries through Antwerp are much delayed. British makers are obtaining good export orders and also large specifications from home railroads.

G. H. Woodroffe, metallurgical engineer of the Parkersburg Iron Company, Parkersburg, Pa., con-

tributes an article to this issue describing the production of charcoal iron tubes.

A complete report is given of the transactions at the Atlantic city meeting of the American Ceramic Society.

A bill is introduced in Congress to put the department of commerce foreign representatives on a more stable basis. The legislation provides for a continuance of service on a basis not possible under year to year appropriations. The House Immigration Committee has reported a bill that would reduce the yearly quota from 350,000 to 150,000.

Average wages of employees in iron and steel works in December was \$130.80, the highest monthly average since 1917.

FEBRUARY 21

Substantial sales continue to be made in the pig iron market, one of the conspicuous transactions of the week being the purchase of 25,000 tons of foundry grades by the American Radiator Company, Buffalo. Basic is selling at \$22, Valley, and foundry at \$23 to \$23.50, Valley. Large shipments in some instances surpassing current output, are reported by representative makers. Iron Trade Review's composite of 14 iron and steel products this week is unchanged for the first time in many weeks, at \$43.53. Steel needs for second quarter are being covered in good volume, bookings by leading mills at Chicago being 25 per cent ahead of those of January.

The steel industry in general is operating on 86 per cent of ingot capacity while the steel corporation is running above 94 per cent. Japanese steel requirements from American mills are estimated at 1,000,000 tons, to be spread over a period of time.

The Ford Motor Company has issued the first inquiry of the season for iron ore asking prices on 250,000 tons. Ore producers say that shipments this year will approximate 60,000,000 tons, but they will not be in a position to quote prices until the latter part of March.

At New York and Philadelphia, 8,000 to 10,000 tons of French and Belgian bars and shapes have been bought around 2.00c per pound delivered, duty paid. The British dock strike has tied up exports in that country. The first day of the strike over 50,000 tons of export steel business was lost to Britain producers. The recent railroad strike was estimated to have cost British Industry \$4,000,000 to \$5,000,000.

An editorial in this issue refers to the recent death by drowning of 41 men in a small iron ore mine in the Lake Superior district and shows how remarkably free from serious accidents is the iron ore industry. The nearest approach to this accident was the drowning of 27 men in 1893, these accidents being in strong contrast with the usual record during the intervening 31 years.

E. F. Ross, editorial representative at Cleveland of Iron Trade Review contributes to this issue, a comprehensive article on the modernizing of a heat treating shop, describing the installation by a Rochester gear manufacture of new high temperature, continuous, automatic, electric furnaces for hardening high speed, gear cutting tools.

An interesting experiment in industrial relations is described. A Massachusetts manufacturing plant employing 3,000 men has dispensed with superintend-

ents, the general manager maintaining contact with the men through 52 foremen.

The Midland Steel Products Company, Cleveland, has adopted a profit sharing plan with some new features, principal of which is the issuance of shares in a fund for distribution among employees. There are 400 shares and the fund is maintained with earnings over a certain percentage.

FEBRUARY 28

The pig iron market this week is quiet, while melters give indication of waiting their chances for lower prices. The markets in some districts, notably Buffalo and the Valley are not as strong as they were three weeks ago. Steel works' operations are nearing the maximum in the Mahoning Valley.

Steel demands for the second quarter are coming out more freely and export business also is increasing, the Steel Corporation's foreign sales at present represent eight to 10 per cent of its ingot output, or at the rate of 1,500,000 tons of finished material annually.

The principal requirements are coming from the railroads and railroad equipment makers, the New York Central having distributed its large order for 14,500 cars, calling for 277,500 tons of steel. At Chicago, 20,000 cars are pending in the market, requiring at least 200,000 tons of steel.

The British dockworkers' strike has been settled quickly as was the locomotive engineering, but before exports were released, the British mills lost large tonnages. Pacific coast users are obtaining steel from Belgium and other European countries far below the American prices, and the London correspondent of Iron Trade Review notes that a tonnage of Scotch pig iron has just been sold for delivery to San Francisco at 025 f.o.b., the freight being \$3.87.

Secretary Hoover states that the agreement between miners and operators in the soft coal fields is the most important made in many years, and it means that stable prices, ranging from \$2.20 to \$2.40 per ton at the mines probably will prevail for the next three years. Coal consumption records compiled by the National Association of Purchasing Agents indicate that business activity gained 21.7 per cent in January.

This issue contains an article, describing the successful operation of hot mills installed in 1923 by the Tin Plate Company of India. The mills are of American design and during the year 213,940 boxes of black plate were rolled under extremes of heat and humidity.

H. Cole Estep, European Manager of the Iron Trade Review analyzes the European steel situation, concluding that a flood of steel into the United States from European countries is improbable, despite recent sales to Atlantic and Pacific Coast points. He points out that large tonnages are not behind the low offers.

An interesting item is to the effect that a government commission appointed to investigate unrest in the steel industry of Canada reports in favor of that industry abolishing the 12-hour shift and the adoption of a three shift plan in continuous processes.

The General Electric Company have developed a distant dial mechanism for use with watthour meters where, for various reasons, it is desired to have the registration of the meter appear at a point remote from that where it is installed.

The POWER PLANT

*Underfeed Stokers and Midwest Coal**

By JOSEPH G. WORKER†

THIS would not be a great engineering society if it excluded rational opinions. It would not be a progressive association if it were to do anything to submerge engineering feeling or subvert engineering theory.

Through your selection of subjects concerning fuel burning equipment for this meeting you will probably get a mixture of all—both feeling and theory.

Finally, however, we must discriminate between theory and good practical operating engineering. Our problem in fuel burning is not entirely one of select-

system that will give the best results from a dollar and cents basis for a particular condition great care must be taken to see that the results obtained are not attributed to other causes than the real ones.

The mechanical stoker has, more than any other piece of boiler room equipment, made possible the present size of boiler plants and the rate at which fuel is now so efficiently burned and utilized. It is also the major reason why we are now installing a boiler horsepower for 6 kw. generator capacity, where 15 years ago we installed a boiler horsepower for 2 kw. generator capacity.

There have been and there are many types of stokers that have been involved in this development. The underfeed stoker has played its part and has figured very prominently in this progress. In order to find out to what extent the underfeed stoker is now used to burn midwest coals, figures were sought with the following results:

A little over 1,000,000 hp. of boilers were sold in the United States during the year 1922 by 28 boiler companies. About 800,000 hp. of all types of boilers were sold. Of these 800,000 hp. of stoker fired boilers 550,000 hp. were equipped with one type or another of underfeed stokers, about 200,000 hp. were equipped with some type of chain grate stoker and about 50,000 hp. were equipped with some type of overfeed stoker. That is, about 75 per cent of the stokers sold in the United States during the year 1922 were underfeed stokers.

From the most exact figures I am able to obtain, with a foundation in the knowledge of the sales of large underfeed stoker manufacturers, the indications are that there were more underfeed stokers sold in the west during the year 1922 than any other type of stoker.

While these sets of figures throw some light on our subject they are perhaps as expressive of economic conditions as they are of differing measures of efficiencies in combustion system. These figures may be surprising, because only a few years ago any of us would have correctly stated that there were more chain grate stokers sold in the west than any other stoker. I am particularly bringing out this point because I want you to get a positive thought in connection with the subject that your committee asked me to talk about and to know what the trend is and not get the thought that I am here talking about something that is new and yet to show its worth and position in the burning of midwest coals.

This change has come about slowly. It may have been delayed at times, but as it grew it accumulated in numbers and gained in power as years have gone by until now we are up to a point where we have



JOSEPH G. WORKER

ing the thermally most efficient system. We must consider those things that are connected with a combustion system that are vital factors in the ultimate results.

Flue gas temperature, preheated air, hollow wall construction, etc., have shown that they can effect the overall efficiency of a combustion system from 5 to 10 per cent. These are not a part of any particular combustion system. In our endeavor to find that

*Paper read before Chicago Section A. S. M. E.

†President, Stoker Manufacturers' Association.

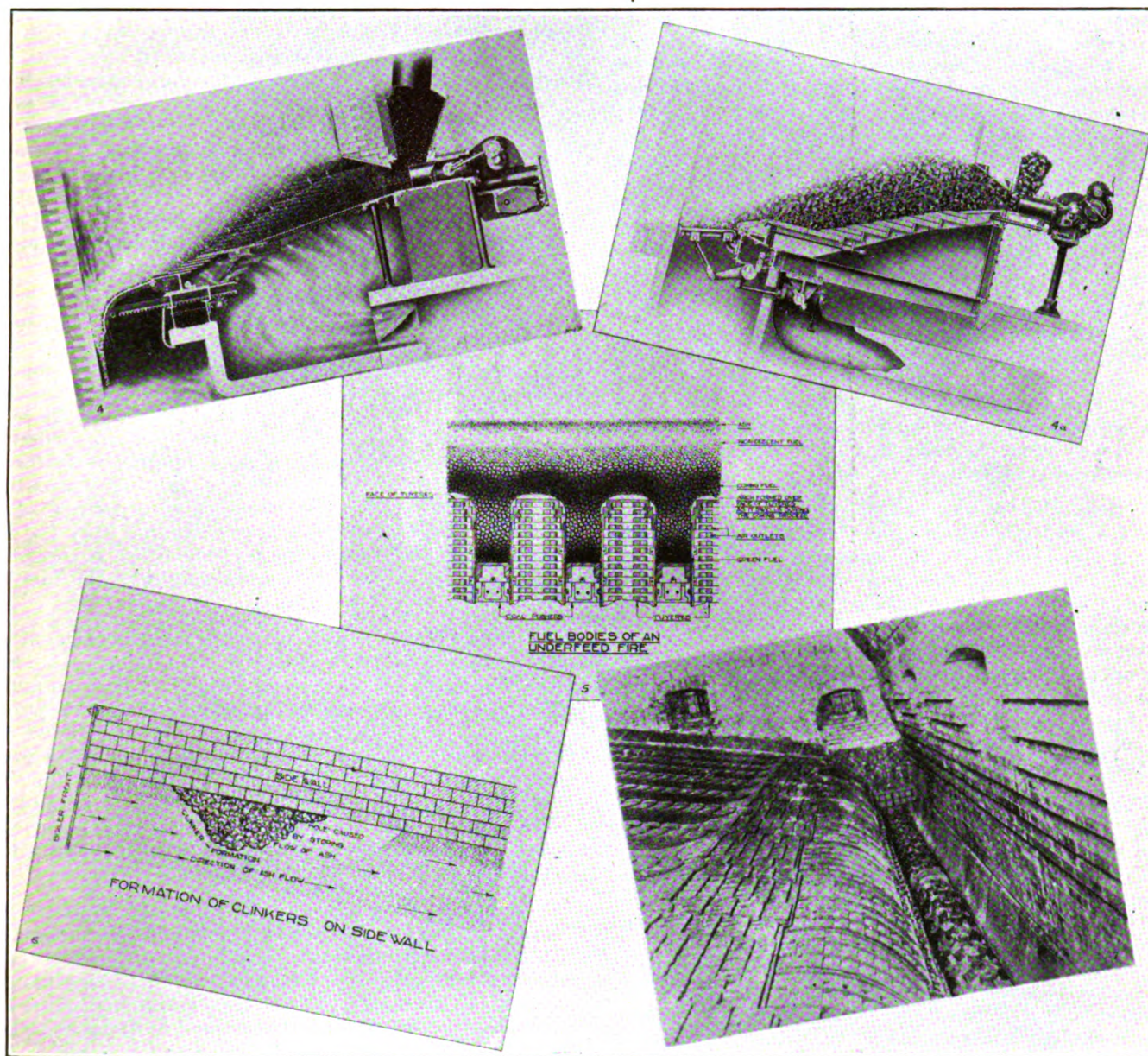
almost as many underfeed stokers going into the west as in the east.

We may have been correct in the past in holding that no stoker handles all grades of coal with the same degree of satisfaction. In that thought, however, we have mixed with it mechanical operating difficulties that were not at all a part of the fuel burning system, but were to quite an extent a part of the cleaning process of a fuel bed.

There have always been two types of stoker designers. One had tendencies towards building a ma-

chine that would offer the best combustion possibilities, irrespective of the cleaning device. Others have mixed the problem to the extent that there have been stokers designed that may not have been the most efficient insofar as burning coal was concerned, but they handled clinkers to such satisfaction that a sacrifice was made of combustion efficiency.

The east went through a partial situation similar to this years ago when the development of the underfeed principle was being taken up by some power stations. Some could see the virtue of this system



Various views which illustrate the typical problems involved in underfeed stoker design and operation.

chine that would offer the best combustion possibilities, irrespective of the cleaning device. Others have mixed the problem to the extent that there have been stokers designed that may not have been the most efficient insofar as burning coal was concerned, but they handled clinkers to such satisfaction that a sacrifice was made of combustion efficiency.

We have heard many times that the underfeed principle was all right for middle west coals, but there

when it was first developed, but it gave rise to endless discussion. It created thought, and what was more, it placed the most severe construction upon the prevailing combustion systems at that time. Nothing could stop this movement after it once started and the faith and character of it led to further development. Improvements were made on one part or another of the controlling mechanism, but the underfeed method of burning coal was probably more than any

other single element the reason for the success of the whole system.

The history of eastern power stations shows nothing compared with the development and use of the underfeed principle. They surrendered individually to a great combustion system and they did that for only one reason and that was that it was a proper engineering movement, and proper engineering movements never fail.

Fig. 1 shows an obsolete setting of a Roney stoker in the east. The Interborough Rapid Transit Company had many of these settings of 600-hp. boiler capacity with a 12 ft. 7 in. furnace width. Note the distance of the front boiler header from the floor line of 7 ft. 6 in. and in some cases 8 ft. A battery of these boilers was about 30 ft. wide. Note the distance from the stoker to the boiler tubes only about 5 ft. Fig. 2 is the replacement valve in underfeed stokers. The underfeed stoker still goes in the 12 ft. 7 in. furnace width and gives 4,800 hp. instead of 900 hp. Over five times the capacity at maximum rating insofar as coal burning is concerned, but only being double the size of the boiler, the new units being 1,200 hp. normal rating.

We sometimes forget that newest stoker developments start in the west, but in a number of cases the problem was never finally and definitely worked out before some other part of the country took it up, and as their coal conditions were not so severe, they gave such an impetus to the business no further effort or money was spent in making a particular stoker suit western coal conditions.

A clear idea of the principles involved in a fuel bed of a multiple retort underfeed stoker is an important consideration. An endeavor has been made to bring out some of the ideas of Elwood Taylor, the inventor of this type of stoker, in a prepared sketch of an underfeed fuel bed. (Fig. 3.) A review of some of the inventors' claims when he petitioned for patents on this device particularly brings out the movement of the fuel. Many have the idea that an underfeed fuel bed is agitated and the fuel is pushed across the supporting structure from the point of entering the fuel to the discharge of ash.

The inventor stated that in the operation of his stoker the fuel bodies in the several retorts constituted legs of a single fuel bed. This fuel bed burned with the incandescent fuel on top and the coking fuel underneath and extending back into the retorts. The fuel bed receives its support from the walls of the retort and, owing to the cohesion and arching properties of the fuel as it swells during the coking process and is fed outwardly by the retort pushers, it is kept substantially free from the tuyere faces by arching over them, as shown in Fig. 3. This sketch also shows very plainly the partially coked coal extending into the retorts and an endeavor has been made to bring out clearly the arches over the tuyeres. This operating principle and claim of the inventor has been demonstrated in research work in connection with this stoker and also substantiated by expert engineering testimony.

Few have considered that underfeed stokers use arches in the combustion process similar to the way chain grates and other stokers use refractory arches. These underfeed arches are made up of partially burned coal and are continuously being burned up

and reformed. Immediately over these arches of partially burned coal comes the incandescent and major fuel bed extending across the openings of the retorts. Finally, the fine ash floats on top of the entire fuel bed (Fig. 4). These particles of ash are small and originally independent pieces. The feed of ash is a gravity feed down the slope of the fuel bed and the movement of ash is induced by the introduction of cartridges of fuel. These cartridges of fuel introduced periodically give a weaving movement to the fuel bed and an outward feed movement across the mouth of the retort.

Very often the idea is advanced that the agitation of underfeed fuel beds is not proper for a high ash coal. A careful analysis of underfeed fuel beds will show, in fact, there is little agitation or mixing of the fuel bed of the kind generally supposed. The injection of these cartridges of fuel is so small that the movement at the time the coal is introduced is hardly perceptible to the eye. Arching of the fuel in the retort also relieves the pressure on these portions of the fuel in contact with the coal pushers when they retract for another charge of fuel so that their movement is always outward.

In its preferred operation, the underfeed stoker is thus distinguishable from those forms of mechanical stokers employing inclined grates in which the feed of the green fuel is an overfeed, along the slope of the grate, produced by a movement of the grate bars. No grate or fuel support such as employed by overfeed or chain grate stokers are used in underfeed stokers, the fuel instead being supported from the retorts. In order to make this clear, Fig. 5 has been shown with all of the supporting structure of an underfeed fuel bed taken away, leaving only the fuel bed. This shows how the underfeed fire is supported on legs of coal and the major weight of the fuel bed is transmitted to the retorts.

The formation and progress of the ash of an underfeed fuel bed is generally misunderstood. There is no progressive movement of ash through an underfeed fuel bed by bushers or rams. It can be proven that the feed of the ash is a gravity feed down the slope of the fuel bed, induced by the feed of the green fuel. A close-up view of the surface of a fuel bed would bring out clearly this idea of the travel of the fine particles of ash down the incline of the fuel bed and the inclination of the fuel bed must be such that the ash will effect this process.

Having developed the principles of a proper fuel burning process, have we given enough thought to the machinery necessary to allow a fuel bed to function according to its principles? If there were no side walls nor bridge walls or other refractory parts surrounding an underfeed stoker and nothing to retard the flow of ash from the top of the fuel bed to the bottom, would clinkers form?

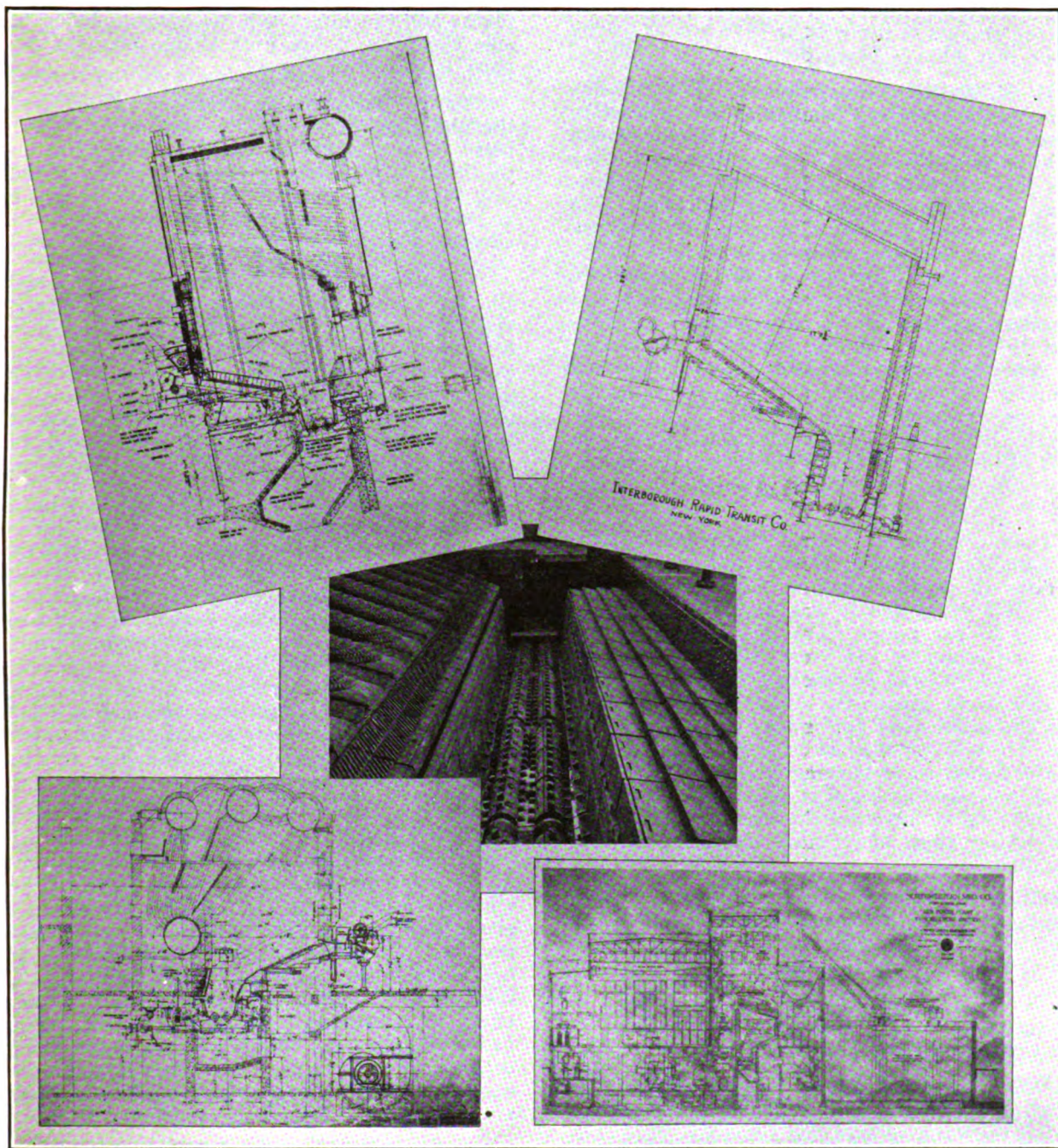
Take for example a particle of ash in a fuel bed, a view of such as shown in Fig. 6, when stopped in its proper course down the slope, adheres to the side wall and backs up the oncoming ash and commences the formation of clinkers. This will gradually grow until it is built out into the fuel bed and underneath it and in some cases down into the retorts unless it is started on its course again.

The development work done on furnace construction for underfeed stokers has brought out sidewall

air plates, air cooled crusher plates, water backs, etc., all to the end of keeping the ash from stopping in its course down the fuel bed. Side wall air backs are now being generally used in connection with underfeed stokers. These plates are working very satisfactorily and of course are much better than the refractory material that was previously used.

on the dump grates, but would build up into the fuel bed.

Without disturbing the underfeed fuel bed principles, the designers tackled this problem and the result was what is commonly termed the rotary ash discharge, shown in Fig. 7. This device is very necessary for continuous and uninterrupted progress of ash



Above are assembled a number of the most modern installations of "underfeeds" for burning Western coals.

If we assume that the progress of the ash is not stopped, but continues down the slope of the fuel bed, the next obstruction is the bridge wall. When multiple retort underfeed stokers were first installed they were equipped with dump grates, and unless this part of the stoker was handled properly, the flow of ashes would be stopped at the bridge wall and a gradual accumulation and backing up of ash would soon result in large clinkers that would not only lay

and clinker from underfeed stoker fires. It is obvious that under certain conditions of operation it would not be necessary to continuously actuate the crusher in the ash well and it is operated to keep in tune with the formation of ash as it proceeds down the slope of the fuel bed. Air backs and water backs are used on the front face of the bridge wall to prevent the stopping of any ash or clinker from continuing its course

down through the ash wells through the crusher rolls into the ash pit.

The thing that is happening today in the west is that some of these clinker problems are being solved and we no longer fear clinkers. At least, we are not stopping good engineering movements just because western coals clinker. For support of this statement, I want to refer to a number of practical installations of underfeed stokers in the west to give you as briefly as possible just what is being done.

The H. M. Byllesby Company was probably one of the first large operating companies in the west to investigate the possibilities of the underfeed system in connection with their many power stations. They have not only put them in widely diversified plants, but are using widely diversified coals with them. The Minneapolis General Electric Company, operated by H. M. Byllesby Company, was probably one of the first stations in the Northwest to install underfeed stokers. The earliest stokers were installed under 12 600-hp. boilers in 1913. The next extensions were installed in 1917, under 1300-hp. boilers, as shown in Fig. 8. The latest installation covers underfeed stokers under 1800-hp. boilers with the use of rotary ash discharge, as shown in Fig. 9. The H. M. Byllesby Company have also installed underfeed stokers in the plants of the Oklahoma Gas & Electric Company, and Louisville Gas & Electric Company, Louisville, Ky.

The Twin City Rapid Transit Company of Minneapolis supplies current to electric railway systems and operates in parallel with several hydro-electric plants. A few years ago it was decided to increase the capacity of the boiler plant and to improve its flexibility and economy. In view of the kind of coal being used, which was Northern Illinois coal, time and thought were given the underfeed stoker to work out the problem of continuous and satisfactory operation. It was established in the beginning that the underfeed method of burning coal was to be used and a trial underfeed stoker was installed. Work was done on this trial stoker until the results sought were obtained. After that many more underfeed stokers were installed.

The setting as shown in Fig. 10 demonstrated that an operating capacity of 350 per cent of boiler rating was possible and at this high rating a low grade coal was used of the following analysis.

Ash	Min. 16 Pct.	Max. 22 Pct.
Sulphur	3.5 Pct.	5 Pct.
Btu. Commercial	8827	9750

Efficiencies were obtained of from 77 per cent at normal rating to 60 per cent at 350 per cent rating. Considering the variable load and the above coal conditions, this performance was better than anything yet obtained at this plant.

The Merchants Heat & Light Company, Indianapolis, in 1911, started revamping their plant and installed underfeed stokers and this led to the installation of underfeed stokers at the LaCrosse, Wis., plant of the Wisconsin Minnesota Light & Power Company, a related property where Illinois coal was used.

As probably most of you know, all of the stations of the Milwaukee Electric Railway Light & Power Company, Milwaukee, except the Lakeside station, are equipped with underfeed stokers.

The United Light & Railway Company of Grand Rapids, Mich., controlling properties in Davenport, Fort Dodge, Cedar Rapids, Mason City, Iowa (Fig. 11), and Moline, Ill., changed over their combustion system in 1912, and since have been installing underfeed stokers. The new \$10,000,000 plant at Moline, Ill., will be equipped with underfeed stokers. A poor grade of Iowa coal is being used in most of these plants and the rotary ash discharge is being used. A side elevation of the Fort Dodge plant of this company is shown in Fig. 12.

Another large power producer in the west using the underfeed stoker is the Consumers Power Company, having plants at Grand Rapids, Flint and Battle Creek, Mich. A side elevation of one of these settings is shown in Fig. 13. The coals that will be used at these plants are extremely difficult to handle, but nevertheless the rotary discharge is being used.

The Central Illinois Lighting Company at Peoria, Ill., have underfeed stokers and have burned some very troublesome coals on them. The Iowa Railway & Light Company of Cedar Rapids, Iowa, changed their combustion system years ago and have since used underfeed stokers. Armour & Company installed underfeed stokers in Omaha and St. Paul, Minn. The Indiana Service Corporation of Fort Wayne have installed underfeed stokers with rotary ash discharge.

In 1913, there was presented before your society the results of underfeed stokers at the plant of the Kewanee Works of the National Tube Company, now the Walworth Manufacturing Company. The feature of the installation was the use for the first time of the Taylor stoker with Illinois coals. At that time very high efficiencies were obtained with Illinois coal averaging about 9700 Btu. That was 11 years ago. The average operating results of this plant for nine years were published not long ago and as a matter of interest are reviewed here because maybe some of you remember the skepticism manifested at the time the original installation was made.

My idea in mentioning these stations in the west that are using low grade, high ash coals with the underfeed principle is to bring out the point that we in the west are getting over our fear of handling clinkers on any kind of a stoker. I do not believe either that we have exhausted our resources in this respect. The feeling that we should leave the fuel bed alone, since it is established that it is an efficient fuel burning method and devote more thought and effort to taking care of conditions that such a fuel bed establishes and change the furnace or bridge wall or any other part of the whole installation that is necessary to get the practical operating results that are necessary.

The Institute of Metals

The annual general meeting of the Institute of Metals will be held, by kind permission, in the House of the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W.1, on Wednesday and Thursday, March 12th and 13th, 1924. The meeting will commence at 10:00 a.m. each day, concluding not later than 5:00 p.m. On March 12 the annual dinner of the Institute will be held at the Trocadero Restaurant, Piccadilly Circus, W.1, at 7:15 for 7:30 p.m.

Bolt Manufacture Simplified

After adopting recommendations calling for the elimination of more than 40 per cent of types of plow bolts, representatives of the manufacturers of bolts and nuts and of agricultural implements, the United States Chamber of Commerce and the American Engineering Standards Sectional Committee embracing 26 other industrial groups, came to an agreement on what should constitute standard sizes of carriage bolts and nuts used in the agricultural implement trade. The conference also voted to recommend to all manufacturers, distributors and consumers that the new program should become effective on new production on January 1, 1925, and on existing stocks on January 1, 1926. The meeting was held in the Department of Commerce, under the auspices of the Division of Simplified Practice, William A. Durgin of the division presiding.

Simplification, Secretary of Commerce Hoover told the conference, represents one of the foremost steps in the reduction of manufacturing costs. Through

the purchase of tools. When he buys a three-eighths wrench it will fit a three-eighth nut—which it frequently would not do in the past."

The sub-committee of the conference, to which was referred the problem of technical standards for carriage bolts and nuts, included A. E. Norton of the American Society of Mechanical Engineers; W. J. Outcalt of the General Motors Corporation, Detroit; H. W. Bearce, secretary of the National Screw Thread Commission; Ellwood Burdsall of Port Chester, N. Y.; William M. Horton of Cleveland, Ohio; J. H. Edmonds of Bethlehem, Pa.; Commander J. B. Rhodes and Commander John N. Ferguson of the U. S. Navy; Theodore Brown of Moline, Ill.; A. C. Lindgren and O. B. Zimmerman of the International Harvester Company, Chicago; Charles T. Ray of Louisville, Ky.; B. J. Kough of Moline, Ill.; C. B. LePage of the American Society of Mechanical Engineers, New York; A. J. Schwartz of the Naval Gun Factory, Washington; F. J. Schlink, assistant secretary of the

STANDARD DIMENSIONS FOR "CARRIAGE" BOLTS

Diam. of Bolt A	Common Carriage-Bolt Head			Button-Head Carriage-Bolt Head			Fin-Neck Carriage-Bolt Head				Ribbed Carriage-Bolt Head			Elevator-Bolt Head			Step-Bolt Head		
	Diameter D	Height H	Length of Square L	Diameter D	Height H		Diameter D	Height H	Length of Fin X	Width of Fin W	Diameter D	Height H	Depth of Rib Below Head C	Diameter D	Height H	Length of Square L	Diameter D	Height H	Length of Square L
3/16	7/16	3/32	3/16	7/16	3/32		15/32	5/64	5/64	3/8	7/16	3/32	1/8	11/16	3/32	3/16	5/8	3/32	3/16
1/4	9/16	1/8	7/32	9/16	1/8		19/32	7/64	3/32	7/16	9/16	1/8	1/8	7/8	1/8	7/32	13/16	1/8	7/32
5/16	11/16	5/32	1/4	11/16	5/32		23/32	9/64	1/8	17/32	11/16	5/32	3/16	1-1/16	5/32	1/4	1	5/32	1/4
3/8	13/16	3/16	9/32	13/16	3/16		27/32	11/64	9/64	5/8	13/16	3/16	3/16	1-1/4	3/16	9/32	1-3/16	3/16	9/32
7/16	15/16	7/32	5/16	15/16	7/32		31/32	13/64	11/64	23/32	15/16	7/32	1/4				1-3/8	7/32	5/16
1/2	1-1/16	1/4	11/32	1-1/16	1/4		1-3/32	15/64	3/16	13/16	1-1/16	1/4	1/4				1-9/16	1/4	11/32
9/16	1-3/16	9/32	3/8	1-3/16	9/32						1-3/16	9/32	5/16						
5/8	1-5/16	5/16	13/32	1-5/16	5/16						1-5/16	5/16	5/16						
3/4	1-9/16	3/8	15/32	1-9/16	3/8						1-9/16	3/8	3/8						
7/8	1-13/16	7/16	17/32	1-13/16	7/16						1-13/16	7/16	3/8						
1	2-1/16	1/2	19/32	2-1/16	1/2						2-1/16	1/2	3/8						

simplification, trade associations are enabled to make contributions on a sound basis to our industry and commerce. The progress reported by the conference, he continued, would be of value to the farmer, and he congratulated the members on their achievements.

A. E. Norton, chairman of the sectional committee, outlining the value of the conference from a technical standpoint, stated that the steps taken would affect certain exports. He estimated that the standardization steps made by this conference in conjunction with other groups would eventually bring about the elimination of more than 50 per cent of the present number of open-end wrench sizes.

"No longer will it be a case of the farmer taking an armful of wrenches out to make repairs—and then not finding the right size," said A. C. Lindgren, of the International Harvester Company, discussing the proposals. "The proposed action will help the farmer in

American Engineering Standards Committee, New York City; Robert S. Burnett, of the Society of Automotive Engineers, New York; H. G. Sameit, secretary of the National Association of Farm Equipment Manufacturers, Chicago; H. J. Hirscheimer, president of the National Association of Farm Implement Manufactures, La Crosse, Wis.

Pemalloy Possesses Remarkable Properties

One of the most striking features of modern scientific research is the effect on well established arts of developments in fields not, at first sight, closely related. New industries have grown from such origins. In other instances quietly conducted abstruse investigations have greatly increased the usefulness, and, therefore, the value, of existing properties in which vast sums have been invested.

The announcement was recently made of a new alloy, called permalloy, which has such remarkable magnetic properties that its use in the manufacture of submarine cables will permit messages to be transmitted at speeds many times that now obtainable, and that is only one of the many applications that this new alloy is sure to find. An old message bearer, the cable, with advantages of control and privacy, has been given "new wind" in the race with its young rival in service to mankind, "wireless". Permalloy did not just happen; it is one of many results of modern, methodical, planned research. To be sure, there was pleasant surprise when test after test revealed and proved its remarkable properties.

Permalloy is an alloy of nickel and iron which is characterized by extremely high magnetic permeability at low magnetizing forces. Its extraordinary "magnetic permeability" means the ease with which magnetic "lines of force" penetrate it and make of it an electro-magnet. It is far the most easily magnetized and demagnetized of all metals now known. The particular composition which is best in this regard contains about 80 per cent nickel and 20 per cent iron. The mere mixture of the two metals is, however, not sufficient to secure the highest permeability. A special heat treatment is also required. When properly heat treated its initial permeability is more than 30 times that of soft iron.

Another interesting property of nickel-iron alloys of about this composition is extreme sensitiveness of magnetic properties to mechanical strain. So far as has been determined, however, it is only in connection with its magnetic properties that permalloy is unusual. The X-ray study of these alloys reveals that their crystal structure is like that of nickel. Permalloy can easily be cast in ingots, reduced to billets, drawn into rods and wire, and rolled to thin tape.

To the engineer the discovery of permalloy will mean the accomplishment of results heretofore believed impossible. For the scientist the principal interest in these high nickel-iron alloys may well lie in the large response of their magnetic properties to simple external controls. Without alteration of composition these properties may be adjusted through extraordinary ranges by strain, by magnetization, or by heat treatment. This allows a more definite study of the way in which these factors are related to magnetic properties than has been possible with materials hitherto available in which their effects are comparatively small and may be associated with complicated and irreversible changes in other properties. The behavior of permalloy demonstrates that ferromagnetization is associated with material structure in a different way than are the other ordinary physical and chemical properties, and its extreme sensitiveness to control gives us a powerful method for use in magnetic investigations.

Nickel-iron alloys containing more than 30 per cent nickel and having the arrangement of their crystals characteristic of nickel, possess remarkable magnetic properties. This series of alloys shows no mechanical, physical or electrical abnormalities and these qualities are little affected by heat treatment, which so profoundly affects the magnetic properties.

Much remains to be learned about magnetism, notwithstanding the fact that the phenomenon of magnetic attraction was observed many centuries ago.

Largest Magnetic Iron Deposits Discovered

The largest deposits of magnetic iron ore known to man have been discovered in Russia, it has become known through the visit of Prof. Dr. P. Lasareff, director of the magnetic division of the Physical Institute of Moscow, who is in this country as the guest of the American Society of Zoologists.

Lying near Kursk in European Russia about midway between Moscow and Crimea, they extend for 150 miles, and at one point are 10 to 20 miles wide. The deposits take the form of a great subterranean mountain with its peak 450 feet under ground.

Magnetic observations made primarily for the advancement of science are responsible for the discovery. Prof. Lasareff explained.

For 50 years the compass needle has been known to act strangely in the vicinity of Kursk. The vertical dip was over three times as great as that at the magnetic north pole where the earth's magnetism is felt most strongly.

In 1919 while civil war was still in progress in that region, Prof. Lasareff, using only instruments constructed in the laboratory at Moscow, began a magnetic survey of the area for the Russian Academy of Sciences, of which he is a member. Investigations continued during the summers following, and gravitational measurements were added to the magnetic.

To measure the force of gravity, Prof. Lasareff used the Eotvos balance, a very sensitive instrument invented in Germany, that will detect very small changes in gravity caused by masses in the earth's crust. It is said that this new device is so sensitive that it will detect a man 30 feet away.

Combining the gravitational and magnetic observations, Prof. Lasareff was able to map the deposits of magnetic iron ore before they were discovered.

Diamond and churn drills were set at work at points designated by Prof. Lasareff and the huge ore body of magnetite was actually found. It lies about 450 feet under the surface and already the drills have penetrated over 500 feet without any sign of its exhaustion. The top portion of the deposit analyzes 40 to 45 per cent iron, but deeper portions run over 50 per cent. So colossal is the deposit that Prof. Lasareff would not attempt to estimate the quantity in tons. The next largest known deposit is in Norway and has a length of only about six miles.

After the steel churn drilling tool had penetrated the deposit of ore for about 100 feet it became so highly magnetized that it would attract and hold 10 to 20 pounds of iron.

This summer Prof. Lasareff will make an exploratory trip into Siberia and the same methods of investigation will be used.

Prof. Lasareff believes that with the possible exception of the United States and Canada, Russia is the land of greatest promise for future natural resources.—Science Service.

Pittsburgh, the Billion Dollar Market

will feature among its conventions this year the million dollar Iron and Steel Exposition of the Association of Iron and Steel Electrical Engineers at Duquesne Garden, September 15-20, inclusive. Reservations made in order of application. Address Iron and Steel Exposition, 708 Empire Building, Pittsburgh, Pa.

Some Pointers on By-Product Coke Oven Operations

For results of a study of the low-temperature carbonization of the Pittsburgh and Upper Kittanning coals, made by the Department of the Interior in co-operation with the Carnegie Institute of Technology at the Pittsburgh Experiment Station of the Bureau of Mines, indicate that the regular Pittsburgh bed coal is a good low-temperature coking coal. When carbonized at 550 deg. C. in a stationary vertical retort it will yield 33 to 35 gallons of tar, 3,500 cubic feet of 600-Btu. gas, 1,400 pounds of 10 per cent volatile coke, and 6 to 8 pounds of ammonium sulphate per ton.

The other parts of the Pittsburgh bed, namely, the rooster, the lower roof, and the upper roof, are of similar coking quality, differing only in the quantity of by-products yielded. These decrease in the order given. The yield of tar from the upper roof is only 66 per cent that from the regular seam, and from the rooster coal 75 per cent. The difference is largely due to the variation in the ash content of the different sections, and not to the chemical composition of the coals.

The Upper Kittanning coal is not a good low-temperature coking coal. The coke is not dense, and the yield of by-products is low. This is a semi-bituminous coal with low volatile matter, and was not expected to yield much tar.

The total amount of light crude oil suitable for motor fuel that was obtained directly from Pittsburgh or Freeport coal by distillation at 550 deg. C., and by cracking, is approximately 7.1 gallons per ton, or 2.6 per cent by weight of the coal. The net refined motor fuel from the process is 4.6 gallons per ton, or 1.7 per cent by weight of the coal.

Superheated steam has an effect upon the by-products of low temperature carbonization. The tars obtained were more viscous, and contained a smaller amount of light oils and a larger amount of heavy oils. The amount of the by-products obtained by carbonizing with superheated steam was practically the same as without steam. The steam prevented secondary decomposition to some extent.

Research on the low-temperature carbonization of coal has been in progress for a number of years, the main object being to produce a coke more suitable for domestic use than the high temperature product of the gas-works and coke oven, and at the same time to effect a higher recovery of constituents in the tar oils, states J. D. Davis, fuels chemist, Bureau of Mines, and V. Frank Parry, research fellow, Carnegie Institute of Technology, in Bulletin 8, Coal Mining Investigations, just published by the Carnegie Institute of Technology, Pittsburgh, Pa. Much valuable data have been accumulated, but this has not as yet led to any industrial development worth mentioning in the United States. Since the World War, investigators have been particularly active in England, where one of the main incentives is the production of fuel oil for which that country would like to develop a domestic source. Presumably there is also a good demand for low-temperature coke for open fires in English homes. In Germany, during the war, research on low-temperature tar oils was carried on intensively on account of the demand for lubricants, substitutes for mineral oils, which can be made from refined tars. Considerable quantities of lubricants were made from such tars during that period, but it is doubtful whether these are competing now with imported petroleum oils. Obviously there must exist a definite demand for low-

temperature products before any extensive development of the method can be expected. The abundant supply of petroleum in the United States, and like supply of coal suitable for high-temperature coking, would seem to preclude competition of low-temperature products in either field in the near future. There is, however, a strong possibility of better utilization of waste coals and coals of inferior rank by low-temperature methods, and this phase of the subject should be a fruitful field for research. Further, the utilization of low-temperature tar oils for special purposes, as, for example, for the preservation of timber, is a reasonable expectation; as is also the improvement of high-temperature coke by preliminary low-temperature treatment. These points have yet to be proved industrially practicable.

Bulletin 8, "The Low-Temperature Carbonization of Pennsylvania Coals—the Pittsburgh and Upper Kittanning Beds," may be obtained from the Carnegie Institute of Technology, Pittsburgh, Pa., at a price of 40 cents.

TRADE PUBLICATION

The "Treatment of Boiler Feed Water for Highly Overloaded Boilers" is the subject of a pamphlet by David Henderson of the Dravo-Doyle Company, Pittsburgh, in which he discusses the effect of suspended matter, sodium salts and organic matter in promoting foaming and priming. Cold process softeners, as he points out, leave considerable amounts of calcium and magnesium salts in solution in the feed water, to be precipitated later on in the feed water heater or boiler as sludge. They also usually employ an excess of reagents. Zeolite softeners, on the other hand, while removing practically all calcium and magnesium salts, generally increase the sodium salts considerably more than does the lime soda treatment, particularly where large amounts of carbonates are present. The lime soda process on the other hand, to secure practically complete precipitation of calcium and magnesium without appreciable excess of reagents, the carbonates of lime and magnesium are disposed of without adding sodium salts to the water, and, in addition, organic substances are largely coagulated and removed with the calcium and magnesium precipitates. Subsequent filtration through non-siliceous filtering material, which is not soluble in the hot alkaline water, gives a crystal-clear boiler feed supply which will not deposit scale nor form sludge in the boilers, which can then be operated at the highest ratings with a diminished tendency to priming or foaming and the minimum amount of blowing down.

TRADE NOTES

A. J. Boynton, for four years vice president and general manager of the Woodward Iron Company, Woodward, Ala., has severed that connection and joined the firm of H. A. Brassert, Inc., consulting and operating engineers, Chicago, Ill. Prior to his association with the Woodward company, Mr. Boynton was for many years at the Lorain Works of the National Tube Company, ten years as blast furnace superintendent of docks, coke plant and blast furnaces.



C. I. Ilgenfritz has resigned as vice president of the Stroh Ilgenfritz Company to become assistant purchasing agent of the Youngstown Sheet & Tube Company, effective March 1. He was formerly purchasing agent of the Brier Hill Steel Company.

F. B. Zopf, for the past 20 years identified with the Riter-Conley Company, Pittsburgh, and for the past 10 years as sales manager of the Youngstown Boiler & Tank Company, Youngstown, Ohio, with headquarters at the home office.

Martin J. Lide, consulting engineer, Birmingham, Ala., is scheduled to speak before a meeting of the American Society of Mechanical Engineers at the Hillman Hotel, Birmingham, March 19, on powdered coal and waste heat dryers.

J. L. Adams, district sales manager at Cincinnati for the Bethlehem Steel Company, has resigned, effective March 1, and will open an office in Cincinnati for the sale of iron and steel products. He is well known in iron and steel circles in the Middle West, having been connected with the industry practically his entire life. He was first associated with the Globe Rolling Mill Company, later joining the forces of the Cambria Steel Company and the Midvale Steel & Ordnance Company and served as manager of sales in Cincinnati for the two latter companies. Upon their absorption by the Bethlehem Steel Corporation, Mr. Adams retained his position as district manager until his resignation. He will be succeeded in the Cincinnati office by John Hennessy, who has been connected with the Bethlehem Steel Company at Chicago.

J. W. Bell, who was consulting engineer in charge of the tin plate plant development in India for Perin & Marshall from June 1, 1922, until the completion of the plant, arrived in the United States on February 5 from England on a business visit preparatory to establishing himself in London as a member of Douglass & Bell, marine and mechanical engineers.

H. C. Thomas has resigned as vice president and assistant general manager of the United Alloy Steel Corporation, Canton, Ohio, which position he had held for 18 months. He will take an extended vacation and will sail from Los Angeles in March for a trip around the world. At a farewell dinner his associates presented him a gold watch as a token of their esteem.

H. H. Davis, who as recently announced, has been appointed general manager of sales for the Molybdenum Cor-

poration of America, Pittsburgh, has been identified with the alloy steel and ferroalloy business since 1907, the year following his graduation from Stevens Institute of Technology. He became identified with the Railway Steel Spring Company in 1907 as a designing engineer, later becoming assistant purchasing agent, then assistant to the vice president in charge of operations. He severed that connection in 1912 to accept a position with the Crucible Steel Company of America in its spring department, and in 1914 became assistant to George M. Sargent, then vice president in charge of alloy steels of that company. In 1916 he was made assistant general sales agent in charge of alloy steel sales in Pittsburgh, and in 1922 became assistant general manager of sales for the Pittsburgh Crucible Steel Company, a subsidiary of the Crucible Steel Company of America.

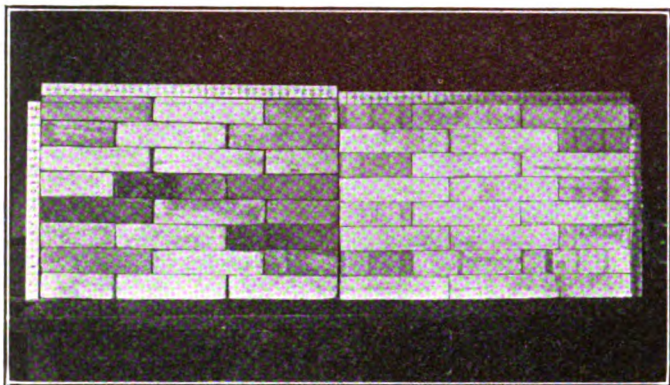
National Immigration Conference

Special Report No. 26. This publication of the National Industrial Conference Board presents a complete record of the discussions on the major aspects of the immigration problem at the national conference assembled under the auspices of the board for the purpose of securing the free exchange and clarification of public opinion on this important and timely question. The conference was attended by over 500 individuals and representatives of national organizations, state and Federal departments and of foreign governments, concerned with the formulation of a new immigration policy to succeed that expressed in the present law expiring June 30, 1924. The views of social organizations, Americanization workers, scientists, educators, foreign language groups, government officials, labor unions and employers on such problems as improvement of administration of the law, changes in the extent and basis of quota restriction, means of selecting, distributing and assimilating immigrants, and other aspects of immigration policy are fully and representatively set forth in systematic and convenient form. This report is an important and timely contribution to the discussion of a pressing problem vital to the social and economic welfare of the country. Copies (\$2.00 paper bound, \$2.50 cloth bound) are ready for distribution and may be obtained from National Industrial Conference Board, 10 East Thirty-ninth Street, New York.

WITH THE EQUIPMENT MANUFACTURERS

New Fire Clay Brick on Market

Realizing that in the brick lining of any metallurgical operation the weakest point is the joint between the brick, engineers for a long time have desired a brick uniform enough in size so that such joints would reach the vanishing point. In blast furnace linings, in coke oven operations and in heating, heat treating and other mill furnaces, the tighter the joint or the closer the brick, the longer the life of the furnace lining. In fire boxes under boilers a fire brick of dependable uniformity has been an essential long desired. At a meeting early this year of the Metropolitan section of the A. S. M. E. in New York, Edwin B. Ricketts, assistant



to chief operating engineer, New York Edison Company, speaking as one who has made a special study of boiler wall construction, emphasized the major importance of uniform size, since lack of uniformity made thick joints necessary, these being the starting point for the destruction of the walls. The ideal was a brick-to-brick contact with only a thin wash of fire clay to fill the pores. It is clearly evident that in a blast furnace, the use of brick so uniform in size that the lining made with them would approach in continuity a solid mass of fire clay should insure much less liability to disintegration and hence a longer life.

A new fire clay brick, for metallurgical and other purposes, which it is claimed meets the ideals briefly outlined above, has been put on the market by the General Refractories Company, 117 South Sixteenth Street, Philadelphia. It is made by a new process patented by the company and developed at the Olive Hill plant of the company at Olive Hill, Ky. It is the result of extensive experiments conducted by the company over a period of years, the aim being to produce a brick so uniform as to reduce joints all possible.

The new process is claimed to turn out a brick absolutely uniform in size and with no sacrifice of quality. Essential features are described as regulation in the mixture, grind and density. Some of the brick made by the new process are shown by the illustrations. In one of these there is a comparison between a uniform brick made by the new process and a pile of brick of the same dimensions not made by this process, but representative of fire brick hitherto used. Several piles of 3-inch thick brick made by this

process, six high, showed a total variation of less than 1/16 inch, or less than an average of 1/96 inch for each brick. The other illustration represents a stack of standard blast furnace sizes made by the new process. Plans are under way to equip other plants of the company to manufacture by the new process. The new brick are now being used by some of the company's principal customers, including many large steel plants.

It will be interesting to learn whether brick, made by this new process, will insure a materially longer life than the less uniform-sized brick, quality being unchanged. Already blast furnace records in the older form of brick have shown an output of 1,500,000 tons of pig iron on one lining. If the new brick can improve on this there will be also the added advantage of the elimination of extra cost due to cutting of brick to fit and of the large amount of bonding material usually used to fill up joints, failures often resulting.

New Clark "Duat" Tractor

The "Duat", the smallest industrial truck and tractor ever built, has just been announced by the Clark Tractor Company, Buchanan, Michigan, manufacturers of gasoline industrial trucks and tractors.

The "Duat" Tractor is a compact, 3-wheeled gasoline powered mobile crane, truck and tractor. It



pivots on one wheel and has a turning radius of but 52 inches. It turns around in a box car. It is an inexpensive general utility haulage unit.

The "Duat" Tractor tows from seven to 10 tons or from one to 20 trailers, depending

on condition of the factory floor or yard. Through an ingenious device, a one-ton crane is attached to the "Duat" without the use of tools, in less than five minutes, converting the "Duat" into a mobile crane. The crane attachment will lift and carry loads up to 2,000 lbs. A brake device permits the load to be carried at any height up to 56 inches; load may be lowered at will. The machine has been designed for the loading and unloading of box cars, the lifting and towing of loads through narrow factory aisles, and for inter-plant haulage.

Like all Clark tractors, it is of 3-wheeled construction. Ample traction is provided by 16-inch wheels equipped with 3 1/2 inch solid rubber tires. The "Duat" has a wheelbase of 40 inches with a tread of 33 inches, and will enter and turn around in a freight car. A brake beneath the driver's seat which automatically stops the machine when the driver dismounts is a safety factor.

NEWS OF THE PLANTS

The Tonawanda Iron Corporation, North Tonawanda, N. Y., an interest of the American Radiator Company, Buffalo, N. Y., has preliminary plans under way for extensive additions and improvements in its plant. It is proposed to construct two new blast furnaces in the near future, with battery of by-product coke ovens, estimated to cost well in excess of \$1,500,000. The project includes the construction of a new ore bridge and bin system. The present plant consists of two blast furnaces, one of which is now in service; the other stack will be remodeled and improved, and considerable additional auxiliary apparatus installed. Also, the present hand-filled method of operation will be changed over with skip hoist installation, and the capacity of the unit increased to 400 tons. The plant was taken over by the American Radiator interests about a year ago for the production of pig iron for its various manufacturing establishments in different parts of the country. Contract has recently been awarded for the construction of a new dock at the plant, and this work will proceed at once. Freyn, Brassert & Company, 122 South Michigan Avenue, Chicago, Ill., are engineers for the proposed new work.

The Braeburn Alloy Steel Company, Braeburn, Pa., represented by Burgwin, Scully & Burgwin, 621 Bakewell Building, Pittsburgh, Pa., recently formed under state laws with a capital of \$1,000,000, has taken over the local plant of the Marlin-Rockwell Corporation, New York, and will remodel and improve the plant for the manufacture of alloy steel products. It is proposed to develop a maximum capacity of 16,000 tons per annum, divided into electric steel and crucible steel ingots. There are two crucible furnaces at present, one of 24-pot and the other of 26-pot rating, and it is purposed to improve these units. Two 6-ton furnaces will also be placed in service. The new company is headed by D. T. Sipe, formerly head of the Vanadium Alloy Steel Company, Latrobe, Pa., who will act as president for the new corporation; G. H. Neilson, formerly president of the Braeburn Steel Company; G. W. Yealy and A. J. Barnett. The two last noted will be treasurer and secretary, respectively.

The West Chester Steel Products Company, Lanape, near West Chester, Pa., recently organized by Charles B. Fairweather, formerly associated with the Downington Iron Company, Downington, Pa., has acquired local property heretofore held by the West Chester Railway Company, and will convert the structure into a new mill for the manufacture of a line of steel products. It is proposed to install equipment for the employment of about 75 men for initial operations, and this number of workers will be increased in the near future.

Jacob D. Waddell, formerly president of the Mahoning Valley Steel Company, Niles, Ohio has acquired the Empire plant of the Brier Hill Steel Company in this same city from the present owner, the Youngstown Sheet & Tube Company, Youngstown, Ohio. The new owner is arranging for the organization of a company to operate the mill, which will be placed on a working basis at an early date. Tentative plans are under consideration for the remodeling of a portion of the plant for greater capacity and efficiency in production, and it is likely that this work will be carried out in the near future. The plant consists of eight black sheet mills, three cold mills and auxiliary structures, with six annealing furnaces and four galvanizing pots. The plant has

a rated capacity of about 40,000 tons of black sheets and 41,000 tons of galvanized sheets per year. The new owner plans to limit the present production to black sheets only, probably developing the galvanized sheet end of the business later on.

The American Sheet & Tin Plate Company, Frick Building, Pittsburgh, Pa., has secured an appropriation of about \$800,000 from the parent organization, the United States Steel Corporation, for extensions and improvements in its plant at Farrell, Pa. Plans are in progress for the construction of four new sheet mills at the works, and it is expected to proceed with the project at a very early date. The structures will provide for an increase of about 50 per cent in capacity, and will have facilities for the employment of approximately 400 additional men.

The Horton Steel Company, Bridgeburg, Ontario, Canada, will commence the immediate reconstruction of the portion of its local plant destroyed by fire a number of weeks ago with loss estimated in excess of \$75,000. In connection with the rebuilding, it is proposed to provide considerable increased equipment for larger output. The new plant will be completed and equipped at the earliest possible date, and placed in service.

The Carnegie Steel Corporation, Carnegie Building, Pittsburgh, Pa., has plans in progress for extensions and betterments in its plant at Homestead, Pa., to be carried out over a period of a number of months, involving a total expenditure of \$20,000,000. The initial work, according to present intentions, will include remodeling of several of the structural mills at the works, consisting of building enlargements and the installation of additional equipment, as well as the modernizing of present apparatus. At a later date, it is said that the program will be devoted to other rolling mills at the plant, with the installation of new machinery.

The Ashtabula Steel Company, Ashtabula, Ohio, has completed plans and will soon commence the construction of a new finishing mill at the local plant. It will be a complete operating unit, comprising pickling apparatus, cold roll equipment, traveling cranes and other apparatus. The production will be devoted to high finish sheets suitable for the automobile industry. It is expected to have the unit ready for service at an early date.

The Kalman Steel Company, Chicago, Ill., operating a steel fabricating plant, has acquired the plant and business of the Corrugated Bar Company, Buffalo, N. Y., with branch mills at Hammond, Ind., Boston, Mass., Philadelphia, Pa., and Atlanta, Ga., all devoted to bar fabrication for concrete-reinforcement work. The purchasing company will take immediate possession, and will merge the acquired interest with its present organization. The Kalman company name will be maintained, with an increase of \$2,000,000 capitalization to provide for proposed expansion in operations. The different fabricating plants will be continued in service, with probable extensions in the future. Paul J. Kalman will be president of the consolidated organization, and is also chairman of the board of the Globe Steel Tubes Company, Milwaukee, Wis. George E. Routh, Jr., a prominent official in the Kalman company, will be vice president of the new corporation, while J. A. Cathcart will act as assistant vice president.

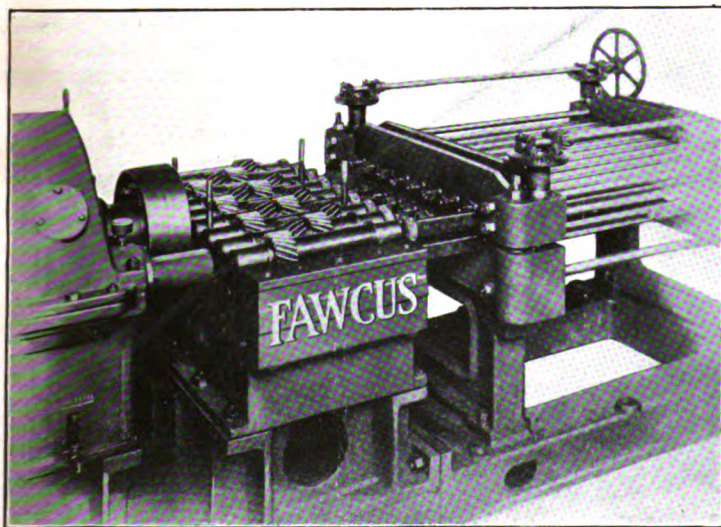
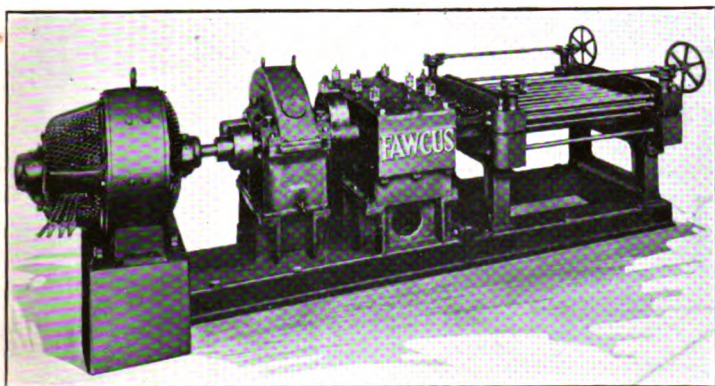
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